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JULY 2016
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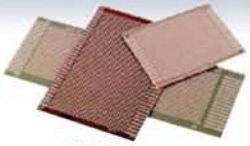
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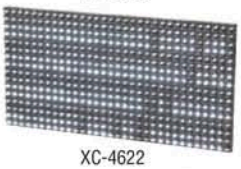
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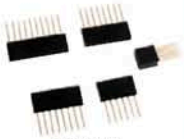
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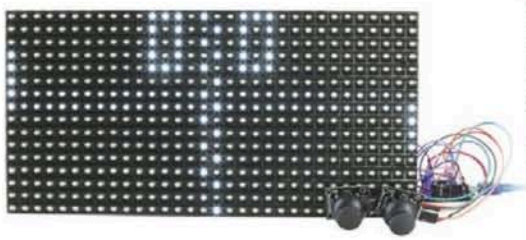

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Publisher's Letter

Drilling for oil and our need for fossil fuels

This month, we have a very interesting article on the topic of Directional Drilling by Dr David Maddison. In many ways, it is a mind-boggling concept, whereby an underground drill can be steered and directed to an oil or gas deposit which may be kilometres from the drill head and may be under rivers, cities or under the sea.

Of particular interest are the ways in which the drill head can be steered and the ways in which signals to and from the drilling motor are fed to and from the surface. As you will see when you read the article, electronics may or may not play a part in this process and nor is the drilling head necessarily powered by electricity. How is that? Read the article.

However, I will not be surprised if some people are affronted by the idea that we would give any space or publicity describing the technology which is commonly associated with "fracking" (hydraulic fracturing of oil-bearing shale). In fact, such people typically want to suppress any discussion which might be seen as favourable. Well, that's just silly.

In fact, using the technique of directional drilling, whether or not it is associated with fracking, is a much more environmentally acceptable way of extracting fossil fuel than any form of open-cut mining. Open-cut mining causes enormous damage to water tables and requires extremely costly remediation after the mine has reached the end of its life, or more likely, has become uneconomic.

But it seems to me that open-cut mining for coal will continue to be used far into the future, regardless of whether we cease to have coal-fired power stations or not. For a start, much of the coal mined in Australia is exported and not used locally. Second, possibly half the coal mined all around the world is coking coal, used in steel-making.

And no matter how much the greens may want to stop coal mining, there is no other way to make steel. In fact, it often seems to me that a large part of the population does not have any understanding of the carbon reduction process whereby iron ore is turned into steel, usually by way of conventional blast furnaces and later refinement involving the addition of nickel, tungsten etc. We must continue to make steel. After all, even those "wonderful" sources of so-called "renewable energy", namely wind turbines and their massive towers, require vast quantities of steel, not to mention concrete which also requires coal for its manufacture. And we must continue to use oil; in huge quantities.

So let's look in favour on directional drilling techniques. They allow us to access oil and gas reserves in the most economical and least environmentally damaging way. The technique has also effectively quashed the doom-sayers' concept of "peak oil", whereby we were supposed to start running out of oil by 1970, 1980 or 1994 or whenever the prediction was shifted to in the face of mounting evidence against it. Of course, such doom-sayers looked forward to the eventuation of "peak oil" as finally preventing man from burning such fossil fuels. They wanted to stop it.

Let's face it. Everyone on the planet utterly depends on fossil fuels for every aspect of our welfare, whether it is clean water, safe sewage disposal, clean and plentiful food, warm and safe housing, modern medicine, all motorised forms of transport, communications and so on. To deny that fact is utterly stupid. In fact, only a small portion of the worlds' population would even exist today, were it not for our widespread use of fossil fuels.

Leo Simpson

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Mains grid synchronisation

In the March 2016 edition of SILICON CHIP I came across something in the Mailbag section which worries me. Gerard Gibbons asked about synchronising an "islanded" solar power system when the grid came back online. The response by Geoff Woodman is the worrying part.

He states that the contactor solenoid must be energised from the grid before the system can be connected back onto the grid – NOTHING about how to synchronise the solar system to the grid. There needs to be a phase comparator to allow the solar inverter to check the AC waveforms so that it can vary the output to be in phase with the grid BEFORE the solar inverter is connected back onto the grid.

Going online without having the waveforms matched within ±5°, as Geoff suggests, can have some very dangerous consequences depending on how far out the phase variance is.

The worst case scenario that I can imagine is the contactor/inverter exploding and causing a major fire. Even if there is no death, there would be major damage to the building which will cause problems for the owner/residents.

These articles are for generators but cover the salient points quite well on synchronisation and WHY it is needed:

http://electrical-engineering-portal.com/preparing-to-synchronize-a-generator-to-the-grid

www.supergen-amperes.org/Library/Out-of-phase%20synchronization%20of%20a%20small%20alternator.pdf

Brad Coleman,
Brisbane, Qld.

SMD soldering: a simple method

Soldering surface mount components can be a chore and sometimes you need a third hand to accomplish the task. To make the job a little easier, I use the following simple method:

To begin, pre-solder any one of the PCB pads that will be used to mount the part. Then while holding the part with tweezers, align it centrally and squarely over the PCB pads and apply a small downwards pressure. Reheat the solder with the soldering iron and the pin will sink down into the pooled solder until it contacts the PCB. Quickly remove the iron to avoid overheating and wait briefly until the solder solidifies.

The part is now firmly held to the PCB. If you are satisfied with the positioning, the other pins can then be soldered normally. When completed, it is possible that the first connection didn't take properly and if you suspect a dry joint, quickly resolder it, remembering that these components are small and too much heat may damage them.

Tony Nixon,
Skye, Vic.

What are "regulating" electrolytic capacitors?

In the Vintage Radio section of the March 2016 issue of SILICON CHIP there is an extract on page 84 from the HMV service manual for Models 209/660. There is a paragraph in the extract

Mobility scooter speed controllers are not simple

Your Publisher's Letter for May 2016 was nice to read and the article by Dr Maddison was superb, as usual. However, I must make a comment about the recommendation of the SILICON CHIP speed controller for use with a mobility scooter as suggested in the Ask SILICON CHIP section of the same issue (page 98).

I have repaired quite a number of mobility scooters and electric wheelchairs and their speed control is somewhat more complex than the SILICON CHIP motor controller. Firstly, a 20A capacity would most likely be insufficient. Although I do not know the stall/start-up current for a scooter motor, a smaller Bosch 24V windscreen style motor has a start-up current of 28A and a no-load current of approximately 2A. With the large inertia of the scooter and driver, the motor will be drawing a large current for appreciable time if the driver decides to accelerate fast; and they often do.

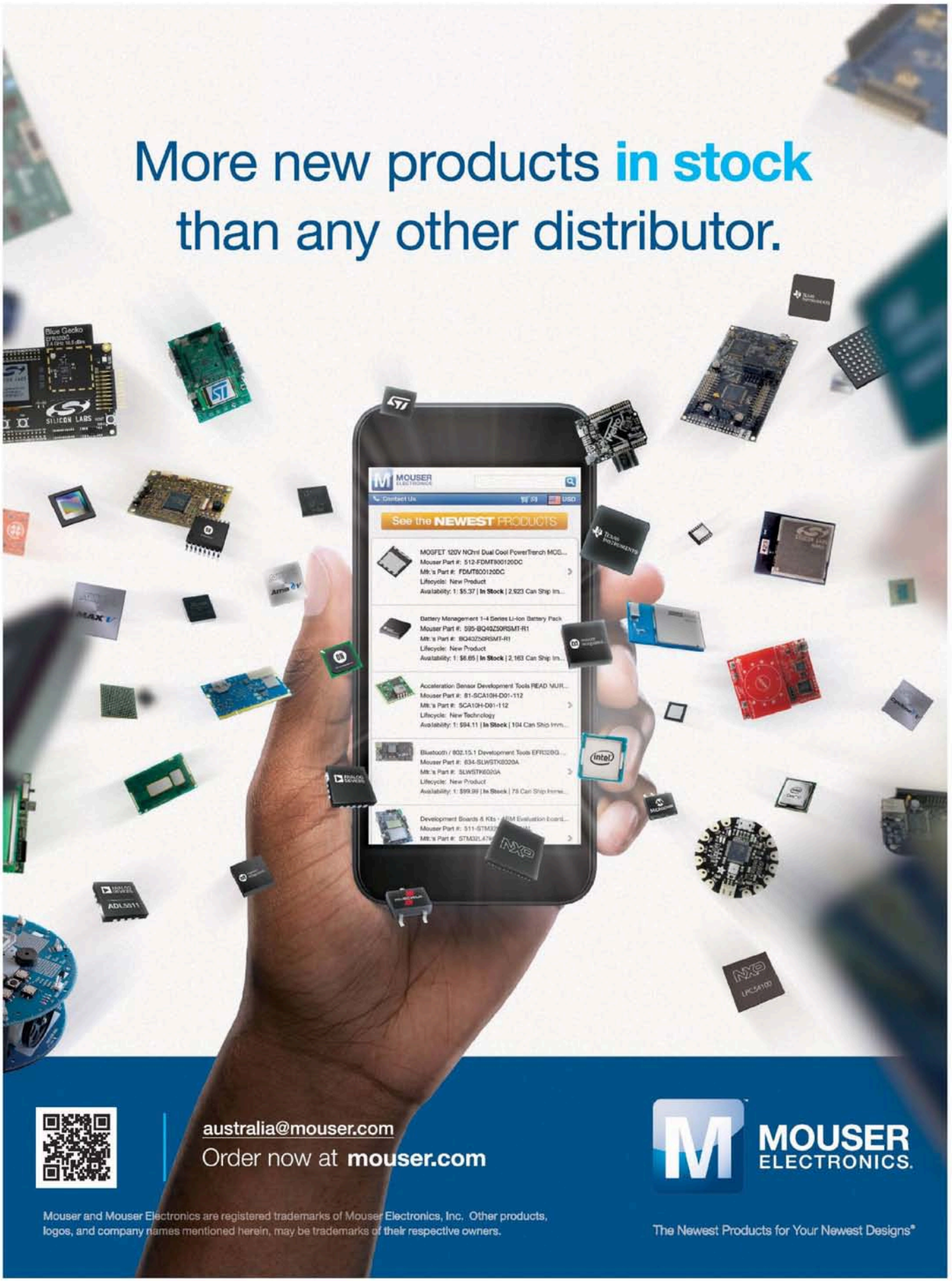
Also, the controlling potentiometer is usually operated using dual wands like a rocker switch with a central off position and a total movement of approximately 13° each way for forward and reverse. The trick to these potentiometers is that when the track is broken, the scooter will not operate despite full forward or reverse voltage being sent to the controller, ie, the controller is fail-safe.

Also, there is a second potentiometer labelled "Hare/Tortoise" which is used to set the speed range. Some scooters are capable of 25km/h so it is necessary to be able to limit the maximum speed around the home.

Another point is that all the scooters that I have worked on have magnetic brakes on the motor shaft. Extra circuitry would be needed to control it since the brake does not normally engage until the motor stops. If it was controlled simply by the potentiometer, releasing the control would most likely result in a handbrake type slide.

Finally, all scooters and wheelchairs have an interlock that prevents operation when the battery charger is connected and some automatically turn off if the correct start sequence is not used.

George Ramsay,
Holland Park, Qld.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Mailbag: continued

The challenges of learning to program microcontrollers

I read the April 2016 Publisher's Letter, regarding the Arduino, Raspberry Pi and Maximite with concern. I realise it was something I had been expecting for some time but hoped that somehow it wouldn't be thrust upon us for a little while yet. However I admit you are correct, we are living in the digital age and there are fewer and fewer things done analytically these days.

Gone are the good old days when you could patch together a few components and see something magic happen. You didn't understand how it performed the magic; that came later when you were drawn in by the sheer thrill of the magic and had the incentive to struggle with the concept so you could build and construct more complicated devices.

And that brings me to the issue I have with the microcomputer chips built into circuits I have struggled with since trying to get into them several years ago.

Most of the books on computers take the approach that if used for teaching how to drive a car would require you to study metallurgy on how the car was built, organic chemistry to understand how the fuel is used, physics to understand the forces acting on the car and psychology to understand what is happening with other drivers on the road. All useful I'm sure but we get by without them in learning how to actually drive a car.

I have bought several books on the subject and despite the "need no prior knowledge of computers" on the cover, they go into so much detail concerning protocols, how pins are addressed and bits stored in registers that by the time you get to the actual programming you have quit or have discovered that the chip they were describing has been superseded and the newer version doesn't do those things. And even if you did get that far, you discover that you have to download files that your anti-virus program goes ballistic about and strongly recommends you have nothing to do with.

And even when you can get a program listed you discover the programmer has abbreviated many of the instructions to save his time and the space taken up by the program, leaving the beginner lost as to what it is doing and how.

Because of the above problems I was excited when the Maximite appeared but was disappointed to discover it didn't exactly speak the BASIC dialect I used years ago and some features had changed.

I searched in vain for examples of programs which had features I might use but was generally thwarted by my anti-virus program and the abbreviated programs.

Therefore I was wondering if you could publish an article "The Dummy's approach to writing BASIC programs for the Micromite". With each part of the program described in detail, and simple circuits to build and illustrate what the program is doing.

Cliff King,
Oxley, Qld.

Comment: we will consider a series on programming the Micromite. What do other readers think?

which caught my interest:

"The speaker field winding placed in the negative HT line is used as a filter choke in conjunction with two 16µF wet-type electrolytic condensers, one of which is a regulating type which automatically prevents the rise of voltage beyond a safe limit during the warming up period."

I was interested in the "regulating type" electrolytic capacitor. I have never heard of these. I did an internet search and have not been able to find out anything about them. Would you perhaps be able to ask your Vintage Radio contributor for more details or perhaps do a short article on these devices? Perhaps Jim Rowe may know something about these?

I am aware that you have to be very careful with the voltage rating of the electrolytics in valve/tube equipment power supplies as until the heaters warm up, there is virtually no HT current drawn, so the capacitors' voltage can rise to the peak voltage of the unloaded transformer HT winding. So to have a capacitor which can act like a zener/voltage regulator is of interest to me.

David Williams,
Hornsby, NSW.

Editor's note: I must admit I had never heard of such a device. But we did manage to find the following description via Google:

"The leakage current characteristics of wet electrolytic capacitors are such that when a potential is applied which exceeds the value of the initial formation voltage of the anodic film, a sharp increase in leakage current values is obtained. Advantage of this characteristic is taken in the design of a type of capacitor termed the regulating or self regulating type.

"The normal increase in leakage current with application of potentials in excess of formation voltages can be still further increased by two methods. First, through the use of a low value of voltage of anodic film formation in connection with the use of a relatively high resistance electrolyte and second, through the use of a low voltage of anodic film formation with the use of a relatively low resistance electrolyte.

"It is, however, general practice to rate regulating capacitors at an operating voltage at or slightly above the potential used in initially forming the anodic film. It is also common practice to specify the degree of regulation by specifying a maximum leakage current at the rated operating voltage and a minimum value of leakage current at a higher value of voltage termed the regulating voltage.

"Usually, the regulating voltage specified is 75 volts more than the rated operating voltage. The magnitude of increase in leakage current varies somewhat with the capacity and general type of capacitor" (www.faradnet.com/deeley/chapt_06.htm#regchar)

In other words, these would appear to have been capacitors with steeply increasing leakage current above a certain voltage which resulted in a crude form of shunt regulation. However, the amount of current they can absorb would be limited before overheating

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Mailbag: continued

Magneto circuity in small, portable engines

I am writing in response to a reply of yours to a reader's letter in the Ask Silicon Chip section of your April edition (page 91). It was about a magneto module that used to be available to replace the points and condenser in old portable-type engines. I think you were mistaken in describing this module as CDI-based.

CDI magnetos are very seldom used in small portable engines such as in lawnmowers, line trimmers and chainsaws etc. These use the more traditional induction magneto, the concept being as old as the internal combustion engine itself. This is the type that used to use points and a condenser but now, of course, they don't. From my observations, CDI magnetos are a later development and are generally used in more expensive applications such as in outboard motors and motorbikes.

Pretty much all of the components of an induction magneto are the magnets, which are embedded in the flywheel, and the coil, which has only two wires coming out of it. One of these is the EHT connection for the sparkplug and the other goes to the cut-out switch. The switching electronic circuitry is embedded within the coil/stator assembly and therefore it is not at all obvious as to how these operate.

In old engines, where points and a condenser were used, it was relatively straightforward to observe how they worked. The points are connected across the coil primary and when closed, effectively short it out. When the magnets in the flywheel sweep past the stator poles, a current pulse is generated through the primary winding. The points are timed to open during this period of current flow, thus inducing the required high voltage and EHT at the secondary winding to fire the sparkplug.

The electronic circuit used today that replaces the points is a bit of a mystery, though I have seen a couple of very old designs on the internet. I am reasonably sure that it consists of a switching transistor that switches on in the presence of a voltage and stays on as the current increases. It then latches open at some time during this current pulse phase but I am unsure as to how this is timed.

As your correspondent mentions, there was an aftermarket module available that could be fitted to replace the points and condenser and I refer you to the following links: www.electronicspoint.com/threads/diy-ignition-module-to-replace-points-condencer.270769/ and www.google.com/patents/US4173961

Many years ago, an old mate of mine who used to race go-karts showed me one which he fitted to one of his kart engines and it did work well, plus it was small and easy to install. I'm talking early eighties here and sadly, as your correspondent mentions, they appear to be no longer available.

I hope that this is all of some interest to you and maybe you could investigate the possibility of developing an updated circuit using modern components. I do think that there would be interest in this. Thank you for a very informative magazine.

Grant Saxton,
Waikato, NZ.

and damage occurred. I am also pretty certain that so-called regulating electrolytic capacitors were not manufactured, at least not in Australia, during the 1950s and 1960s.

Air-conditioner standby power update

I had a letter published on page 10 of the Mailbag section of the February 2016 issue, about my concern that the standby power drawn by split system inverter air-conditioners was excessive.

With the clamp meters I used previously I had obtained very high standby power readings from my air-conditioners. Figures of 60W for a Fujitsu inverter spilt system air-conditioner and around 190W for a similar Mitsubishi air-conditioner quite shocked me.

The meter that I now have will measure both real power and apparent power and the real power is 4.5W and 5W respectively, so the air-conditioners are not drawing excessive power on standby. A cheap Aldi watt meter gave readings only a few percent different to the more expensive meter.

My concerns have now been allayed about excessive standby power being drawn by inverter split system air conditioners.

Rodney Champness,
Mooroopna, Vic.

Feedback on laptop repair article

I really enjoyed the article on resurrecting a dead laptop in the June 2016 issue, by Greg Swain. I have also resurrected many a dead laptop, though mainly of the Apple Macintosh variety. I wanted to offer some advice and tips for anyone else who might be thinking of doing their own laptop repairs.

Firstly, don't attempt a repair on a computer that you aren't prepared to throw away. It's very easy to accidentally do irreparable damage, even when you're exercising all care.

Make sure you have the right tools before you begin. Many hardware manufacturers will go to great lengths to try to stop you from opening their devices by using a variety of different screw heads. Get yourself a good set of precision screwdrivers that include Phillips, Torx, hex and tri-lobe drivers.

Another handy accessory is a partitioned container, like those used for storing fishing tackle or hardware fixings. They allow you to place the screws from the laptop into their own separate section of the container, in the order they were removed. Then you can just work backwards through the container compartments during re-assembly.

Buy a roll of Kapton tape. This is the transparent yellow tape often used inside computers for electrical insulation, or for holding wires in place. Rather than trying to save the tape as you remove it, just throw it away and use new tape during reassembly. It's readily available on eBay at low cost and in a range of different widths.

Take photos of absolutely everything. The beauty of modern digital

cameras is the ability to take as many photos as you like. I always take a photo of what I'm working on, right throughout the repair process. Take a photo of what it looks like before you undo the screws, then remove the screws and carefully lie them next to the holes they came from and take another photo. This allows you to see the different screw sizes and the holes they came from. Then place the screws into a compartment of your partitioned container and take another photo without the screws. Do this at every step, and then use the photos in reverse order for re-assembly.

If you need to replace parts, keep an eye out on eBay. People are regularly selling broken laptops for an absolute steal. If you know you have a problem with a motherboard or graphics card, look for one with a busted screen. If you have a busted screen, look for one that won't boot. I've managed to grab broken laptops for as little as $12. I then piece two together to create a single working laptop for less than $30, resulting in a fully functional computer I can re-sell for $300 or more.

One incredibly valuable online resource is www.ifixit.com This site has a wide range of computer parts for sale but more importantly, it has a huge library of step-by-step tear-down instructions with nice, clear images. Sometimes a single step might involve the removal of 20 or so individual screws and the ifixit tutorials itemise the different screw types and sizes and where they all go. Before starting your repair, check and see if your computer is listed on the ifixit website — it could save you hours.

Be careful what you read when using a Google search to find information on your computer's specific fault. There's lots of conflicting information around and not all of it helpful.

In Greg's article about the HP ProBook 4525c, he applied heat to a chip in an attempt to reflow the solder. Unlike Greg's disastrous result, I have had some limited success with this using a small blowtorch and a very steady hand. I have managed to resurrect a couple of computers but the repair was short-lived. Some kept working for a couple of months, others only a couple of days but I've never been able to get a permanent fix with this method. I would always recommend trying to replace the whole board rather than trying to fix a mounted component with heat.

It shouldn't need mentioning but do make sure your computer is outside of warranty before undoing a single screw.

And my final piece of advice is don't attempt your own repair if you don't enjoy it. Some laptop innards are arranged in lots of complex layers, resulting in incredibly tedious and fiddly disassembly. If you don't enjoy that sort of thing, it's likely to take years off your life. If you do enjoy it, the results can be very rewarding and even a little bit profitable.

Bruce Rayne,
Lalor Park, NSW.

Smart meters not so smart for consumers

I love reading the Publisher's Letters about so many issues. I am a farmer these days although I have just sold my farm. Before that, I was a consulting engineer to a new telco in Germany called O.Tel.O which was the first competition to DTAG. Sadly, it was bought, packaged and sent away. We used Ericsson exchanges.

Before that I spent 25 years in what is now called Telstra, ending up as a PTTO3 and then in my last days as a Manager 3. I used to have about 10 staff, more when testing new software. I have been up to my elbows in computers and systems for over 40 years.

At my property, I have a 3-phase connection. The main power lines to Buchan and Gelantipy come through my property. There was a transformer here when I bought the property (the old SEC days) but they took it away without any warning or consultation.

Origin of atmospheric electricity disputed

I read the article on thunder and lightning in the May 2016 issue of SILICON CHIP but it is very involved and I think quite wrong.

When I was young my mother told me that thunder and lightning were caused by the clouds banging together. I am now 80 years old and have no reason to think she was wrong so perhaps you should study it a bit more!

John Breden,
Te Puke, NZ.

Editor's comment: we would never presume to question your mother's wisdom in explaining complex natural phenomena to reassure a fearful little boy. There might even be a grain of truth in it! It also used to be said that thunder was the sound of God moving the furniture around! We will suggest to David Maddison that perhaps he should do a bit more research on the topic.

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Mailbag: continued

Building a replica HP-35 calculator

Back in 1972, Hewlett Packard introduced the HP-35 which was the world's first hand-held scientific calculator with transcendental functions such as trigonometric (sine, cosine, tangent etc) and logarithms. Development cost nearly a million dollars and took two years. It soon began the demise of the slide rule with over 300,000 HP-35s being sold within the first three years.

More calculator models followed such as the magnetic card programmable HP-65 which was used in Apollo missions and business calculators like the HP-80 which introduced keys that performed complex functions. The Classic Series, as they are known, have held their value over the years, with many still working today or restored back to working condition and kept as collector's items.

If anyone has an interest in these old calculators and would like a chance to play around with one, I have developed a suitable project. Visit www.teenix.org where you will find a free Classic Series emulator for the PC and plans to build one of your own.

The project is based on the PIC-16F877 chip and emulates the original calculator code for all models, including the HP-65 memory card. The PCB layout is arranged the same and the display uses similar 7-segment bubble LED display modules, although the PIC has support for a secondary LCD display if required.

The parts are cheap and most are available from Altronics. An accompanying PC program allows you to use each of the calculator types on screen, or open them up and view the working internal registers plus simulate, modify and experiment with the operating code. The PC program also communicates with the calculator via the USB port and lets you upgrade the PIC driver software, change calculator models and transfer programs to the HP-65 memory cards.

I have a few free prototype PCBs remaining from development if anyone is interested in building one. First in best dressed by sending an email to tnixon059@gmail.com

Tony Nixon,
Skye, Vic.

It cost me about $19,000 to get a new 3-phase transformer installed. Then it cost me about $5000 to get the lines into the ground to the shed about 150 metres away and another $7000 to get it to my new house. In between buying the farm and building, the State Government changed all the rules and SECV was no longer, so I had to pay.

So I have three phases to a new stupid Smart Meter at my shed. I can not even park near it as the radiation from this new meter disturbs my radio something chronic. One phase is used for a relocatable house in which my mother used to live. The next phase is used to power the workshop and the third phase is used to power the main residence.

Prior to the stupid Smart Meter, I used to get a reading of each phase. For a farmer doing the right things in regard to taxation and GST, I need to have a reading on the phase that is supplying things like my electric fencing and a storage fridge for animal health medications, as well as when using tools like welders.

I have so many accounts from the "supplier" but they can not give me a breakdown on the usage of each phase. The meter sits there cycling all the time, showing the utilisation of each phase but their system can not seem to provide this information. How dumb is this new "Smart Meter"?

When the meter reader comes out, (yes, they still come out even though they have this new dumb Smart Meter), he gets a reading of each phase. So they do actually know the utilisation of power on each phase but refuse to provide that information. I asked to get this information and they want to install two extra meters at my cost.

All I was trying to do was to do the right thing in my returns for GST and taxation but it seems they have the information but refuse to provide it to the customer. So Smart Meters? Forgive me if I swear. Having spent over four hours on the phone waiting and waiting and getting stupid answers, I gave up.

Doug Stephenson,
Buchan South, Vic.

Comment: the simple answer to this dilemma is to buy three single phase watt-hour meters and have your friendly electrician install them in the locations you want them. You can now purchase single-phase DIN rail LCD watt-hour meters quite cheaply on ebay. For example, see www.ebay.com.au/itm/DDS238-1Single-Phase-DIN-rail-LCD-Kilowatt-KWH-Watt-Hour-Energy-Meter-5-32A-230V-/301444817825

Repairing a flattened radio

As soon as I saw Ian Batty's excellent Vintage Radio article in the January 2016 issue, the photos brought back memories of a repair I carried out on the same type of radio which had been run over by a truck.

I was very keen on electronics as a 15-year old while still at high school and purchased a multimeter and signal tracer in 1964 with pocket money I saved up for a year!

Things in the electronic world were not cheap then and I had to travel for one hour on the train to get to the city to buy components (valves and transistors) and there were only a handful of retail outlets who would sell to a schoolboy!

The multimeter cost me over six pounds from Radio House in Angel Place, Sydney but I knew it would pay for itself and help me to make a profit out of small repair work.

I subsequently repaired a couple of radios and a record player for relatives, friends and neighbours (all valve jobs) and was keen to get into a service career.

During woodwork and metalwork lessons I constructed a pair of "Playmaster Bookshelf Speakers" from the December 1964 issue of *Radio, Television & Hobbies*, combined with the Baby Stereo 2-Watt Amplifier using two 6GW8s, in the May 1964 issue.

One of my classmates, G. S., who saw my work, presented me with a rather

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Mailbag: continued

Reading from an SD card can cause data corruption

I've been using SD/SDHC cards in projects for a few years and have one application in which there's a real issue. Using a dsPIC and SPI, the device reads a small (60kB) file from the card about every two seconds; 40,000 reads a day, every day. The data is transferred to other devices.

I noticed that something odd was happening to this process after a few months. During accelerated testing, several million reads of this or any other file or block leads to an inevitable failure, in which the dsPIC was simply unable to complete a block read, as confirmed by logic analyser captures. The only apparent solution was to format the card and reload the file(s). This wouldn't be convenient in the consumer version of the product.

I did my best to eliminate causes (different cards, files, file location on card, card controller etc) and eventually determined that it is probably due to "Read Disturb", which is seemingly not widely known about, and the fact that I'm using the card in what is probably an unusual, but legitimate, way. I've asked about this on a couple of very relevant forums but no one else had experienced it.

SanDisk has an Application Note in which they mention it, as described below.

I'm not sure if running in SPI mode enables the card controller's firmware to perform error checking, wear levelling, etc which it should definitely do in 4-bit parallel mode. I say "should do"; counterfeits, knock-offs and manufacturing shortcuts notwithstanding.

My initial solution has been to add a 512kB SRAM to the circuit and refresh card blocks on a regular basis, bearing in mind the number of times various files (totalling 400MB) are accessed and overall Write Cycle Endurance of the card vs expected product lifetime (as long as possible).

Another possibility is to have a second card with identical files and refresh from that. After, for example, every 1,000,000 reads from Card1, read file blocks from Card2 and write them to Card1.

Hopefully either of these remedies will keep the card running properly indefinitely. As Sandisk point out, cell size getting smaller only exacerbates the problem, so I've stocked up on 4GB cards whilst they're still available. However, the remedies would still work on larger cards of course, but I may have to revise refresh periods. I could even include a sealed good-quality master copy of the files for re-installing in many years' time but you can't really trust any digital storage to last forever.

Hopefully this is of interest to your readers: **https://www.sandisk.com/content/dam/sandisk-main/en_us/assets/resources/enterprise/white-papers/WP001_Flash_Management_Final_FINAL.pdf**

Read Disturb: A read disturb occurs when a cell that is not being read receives elevated voltage stress. Stressed cells are always in the block that is being read and are always on a page that is not being read. The probability of read disturb is much lower than is a write disturb.

Erasing the cell resets the cell to its original state, eliminating the data and consequently, the data errors which resulted from the read or write disturbs. An ECC mechanism in the data flow path detects bit flips and corrects them before providing the data to the host. As flash cell geometries decrease and more cells are placed onto wafers, the probability of errors and bit flips increases and NAND flash controllers require more powerful error detection/correction (EDC/ECC) algorithms.

Joe Colquitt,
Auckland, NZ.

squashed and forlorn looking radio and asked sheepishly if I could repair it.

At the same time, some other classmates overheard the request and laughed themselves silly, thinking that it was impossible to repair anything that had been run over!

I was determined to have a go at it and I thought that the transistors may have survived (they were really expensive at that time), so I agreed to take on the job.

The case was broken into several pieces and the PCB was also in several pieces but everything was there. The dial, variable tuning capacitor and loudspeaker were OK. After dismantling it all, I began by glueing the PCB together with my trusty aeroplane modelling cement and then bridging all the tracks with wire using the multimeter as my guide. The metal cover needed a little panel beating and I had to replace a couple of damaged capacitors from my junk supply but all the other components looked OK.

After all the case pieces were glued together, like a plastic jigsaw puzzle, I put it back together as if I were carefully building a model so it looked pretty respectable when it was finished. A new battery was fitted and then the big moment; after switching on it came to life with the most beautiful music loud and clear!

I gave it a good soak-test and enjoyed it for a few hours because I didn't yet have a "tranny" of my own! You need to remember in those days that transistor radios were very expensive and that replacement transistors often cost several pounds each when the basic wage was 10 pounds a week!

There were a couple of small problems; the volume control crackled loudly and so this was opened up and cleaned with a cloth (no aerosol cleaners in those days!) and there was also an intermittent open circuit which was very difficult to hunt down. It turned out to be a dry joint caused by the stress of the accident and I made sure it got plenty of solder to aid the strength of the joint.

All in all, it was about a weeks' work for a schoolboy but very satisfying. G. S. was completely bowled over when he received the repaired transistor radio and I was very happy to have made a couple of pounds (dollars had not yet arrived). Later, the news of the repair spread rapidly through whole school and I had teachers and students actually congratulating me for what they thought was a miracle!

Business boomed thereafter and

I was presented with a multitude of faulty record players and transistor and valve radios which required much less effort to repair; it really put me on the map!

Allan Linton-Smith,
Turramurra, NSW.

Distinguishing between AWA 517 radio models

The AWA 517M featured in Vintage Radio, May 2016, is in actual fact an AWA 517MY – see the Radiomuseum website: www.radiomuseum.org/r/amalgamate_radiola_517my.html

There are three mains-powered versions of this radio: 517M, 517MY & 517MZ. The 517MY circuit is a hybrid of the 517MZ and 717C. The 517MZ has the on/off switch and the 717C has the variable tone control.

Kent Martin,
Footscray, Vic.

Vintage Signetics 2650 computer repair

Reading the Serviceman's Log reminded me of a repair job I pulled off, which at the time I thought was pretty special.

Let's go back to the birth of the microprocessor era. A number of 8-bit chips were vying for supremacy, among them the 8080/85 (Intel), 6800 (Motorola), 6502 (Mostek), 2650 (Signetics), Z80 (Zilog) and SC/MP (National Semiconductor). Nearly every major semiconductor manufacturer had a product of some kind.

In those halcyon days, the way for a hobbyist to get into the area was to purchase a "Development Kit," which was a very prosaic PCB-mounted combination of a microprocessor, a ROM-based operating system, a few hundred bytes of RAM, a hex keypad and a LED display. Only later did television-based "glass teletypes" come along. (Editor's note: while it may seem obvious now, this was a major innovation by Apple's Steve Wozniak).

A couple of years later, commercial products like the Altair 8800 and the SWTPC 6800 signalled the beginnings of personal computing. Eventually, cassette tape-based storage gave way to disks, operating systems grew up (which is to say, the kind of facilities that had been available for years on mainframe computers finally became generally available) and the rest is history.

I personally went with Intel but many people were attracted to a kit based on the Signetics 2650. The 2650 was an enigmatic beast, one of the few at the time to operate off a single 5V power supply when most used PMOS or NMOS technology and required multiple supplies – typically -12V, +5V and +12V.

The 2650 also had a beautifully regular instruction set (unlike the concocted horrors of some of its competitors) but with a drawback which proved fatal: an 8-level, hardware-based return stack. And to make matters worse, the instruction set provided no way to implement a regular stack using the available instructions.

I'm digressing a bit but why did this matter? People who have never been exposed to assembly language (let alone hand-assembly to hexadecimal) might not realise that one of the enduring patterns of low-level computer code is the "stack frame," in which subroutine arguments (as many as required) are "pushed" onto the stack before the call is made.

The subroutine "call" instruction pushes the return address onto the stack before jumping to the location of the subroutine. The subroutine accesses the caller's arguments by indexing from the stack pointer (SP). On return, the arguments are "popped" off the stack (or a constant is added to the SP) to clean up the stack frame. With the right machine architecture, this is a highly flexible and infinitely reusable pattern which allows recursion and subroutine nesting.

The 2650 could not support this pattern. Neither, incidentally, can the 8-bit PIC machines, which is why I conclude that their immense popularity is based on factors like low price and a rich array of built-in peripherals, not architectural elegance or scalability. (Editor's note: this is likely why the Arduino group went with Atmel, as Arduinos are programmed in C++ which relies heavily on the stack).

Getting back to my repair job: an acquaintance had purchased and assembled the Signetics development kit and it didn't work. He was out of skills and out of luck.

Like most projects at the time, the

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Mailbag: continued

Wire glue can be most useful

I bought my first copy of Radio, TV & Hobbies in December 1958 and continued to buy it and then EA, followed by SILICON CHIP, until a couple of years ago when I found I wasn't keeping up with my reading and so I let my subscription lapse. Having retired a year ago, I am back to reading SILICON CHIP again.

I can't see myself doing much project building but I do like reading what Leo Simpson has to say in the Publisher's Letter and the other articles. This brings me to the Ask SILICON CHIP pages in March 2016 issue, where two items sparked my interest.

The first was the question about Wire Glue, on page 90. Recently I have been doing battle with a remote control for an air-conditioner which is of a virtually unknown brand and has no control buttons on the unit itself, so without the remote control it is useless. The carbon tracks under the on/off button of the remote control had virtually disappeared.

I did some internet searching and found out about "Electric Paint", which sounded like a possible solution but where to get some in Australia? I rang the Jaycar store at Booval and the very helpful gentleman there suggested that I try Wire Glue (Cat. NM-2831) which they had in stock. I went there that morning and got some and also a roll of adhesive aluminium foil tape.

With the original carbon tracks of the relevant section of the PCB completely removed, I managed to paint on tracks of Wire Glue which were wider than original but adequate for the purpose. I also cut a circle of the aluminium foil tape and put it on the relevant button. The next day, after the glue had dried, I assembled the remote control and am pleased to report that we once again have a working air-conditioner.

The other question that caught my eye was the request for a 6V CDI design, on page 92. In the early 1970s, we had a 6V VW beetle which periodically would not start. Usually, this was when my wife was trying to come home from the shopping centre with two small children and a load of shopping in the car. She became well-known to the RACQ patrol men who were called to her aid.

I was determined to fix this problem and so started looking for a 6V CDI design but to no avail. I had acquired a Mullard brochure that offered a possible solution but it was a 12V design. I therefore spent some weeks of spare time building this unit but changing the transformer windings. I think I rewound the transformer about three times before I got it right but having done motor winding in a former life, that was not a problem.

Eventually I got it to work and it went on to run the car reliably until we changed to a bigger car. One garage mechanic did get a belt from it. He had been warned but chose to ignore the warning but it did have about 200V on the primary of the coil.

It was only about a month later that *Electronics Australia* came out with their 6V design in November 1971 (by Leo Simpson) but at least I had the satisfaction of doing it myself.

Bill Adams,
Sinnamon Park, Qld

risk of damaging static-sensitive components (no static protection in those days!) was minimised by firstly soldering PCB sockets onto the board, then plugging in the components. My acquaintance had done a fabulously neat assembly job and was very disappointed not to be rewarded with a working system.

The tools at my disposal were a 200H multimeter (a popular and cheap moving-coil meter at the time) and a home-made logic probe. The latter was equipped with LEDs to display green for logic low, red for high, and an amber flash for a low-high or high-low transition (a short pulse would otherwise go unnoticed).

I fired up the board. The supply voltages to all chips were perfect, so I started probing around for logic levels. The thing I immediately noticed was that after a reset, there was a short period of frenetic activity on the address and data buses, then nothing. I concluded that the processor chip was in good shape and was probably executing instructions after start-up until something went wrong.

It was time to get systematic. The address and data buses were equipped with buffers (bidirectional for the data bus), right on the terminals of the processor. It took quite a while to test each line, cross-referencing from the schematic to the board and locating the right pins on the chips.

I eventually noticed that the pattern of green/red/amber on one line – address or data, I can't remember – differed between the outboard and inboard sides of its buffer. Ah-ha, a faulty buffer chip, or so I thought until I pulled the chip from its socket and found one pin neatly folded under! I straightened the pin, plugged the chip back in and the board sprang into life.

So my theory was correct – the processor had been starting fine and either putting out corrupted addresses or receiving corrupted instructions until it stumbled upon a halt instruction.

These days, sockets are rarely used and thank goodness for that. Anyway, I thought I had done pretty well to diagnose and repair a computer (a rare and unfamiliar thing in those days) equipped with nothing but an analog multimeter and a logic probe.

Neil Harris,
Grange, Qld.

What makes a radio vintage?

I always enjoy the vintage radio articles which bring back memories of my first job as a radio and TV service apprentice in the 1960s in the UK. This involved taking all the accumulated "junk" to the tip, ie, all the radios and TVs considered to be not worth repairing. There was a panel van full of these nearly each month! What would they be worth now?

Domestic transistor radios were just coming in but most of our work was good old valves with "bitey" HT, especially the TVs which would not pass any safety rules nowadays; live chas-

sis with a 2-pin mains plug which could be connected any way around, etc!

We soon became valve jockeys for the TVs, carrying a large purpose-built box with nearly all the valves we were likely to encounter. If changing the valves didn't cure the problem, then the TV had to be brought back to the workshop for a senior technician to repair. This was not our favourite part of the job as these old TVs were heavy and considered part of the customers' furniture, so look out if you scratched it.

How do you classify a "vintage" radio? At what age does a radio become vintage? I have two radios which I would call classics not vintage:
(1) A Bang & Olufsen Beolit 1501 which I bought new in the early 1970s. This has a slide-rule type tuning scale with ball bearings moved by magnets.
(2) A Roberts R 600 1968-1973, "By appointment to her Majesty the Queen".

The B&O is not working and I hope to repair it soon. The Roberts works well! **M. D., Paynesville, Vic.**

Comment: we put this question on the definition of "Vintage Radio" to Kevin Poulter:

This is an interesting question, given the Historical Radio Society of Australia does not have a definitive answer.

A contributor to Wikipedia states: "An antique radio is a radio receiving set that is collectible because of its age and rarity. Although there is no precise criterion for a radio being antique, typically a 50-year-old or World War II vacuum tube set, and a pre-1960 transistor set".

We would differ on the above by not requiring valve sets to be older. We are very tolerant of age, however would probably cut off at the 1970s. That implies that sets about 40 years old and older are vintage, as far as the HRSA is concerned. So the unofficial answer from us is 40-50 years old.

The practice of looking at a set on site then taking difficult ones back to the workshop was common here too, with the less reputable stores charging a fortune for people to get their sets back. One store had a mountain of unclaimed radios and TVs, as the owner steadfastly kept to high prices.

Of course, we now know that merely replacing a valve was not a scientific repair, as resistors and capacitors could be causing the real problem.

One of our members relates that on the first day of his job, he was told by management to bring a faulty TV back to the store but he had no ropes or padding to protect it. It crashed around in the back of the van on the way and was badly damaged by the time he got back to base.

When I was studying radio and TV at RMIT, we were working on Astor SJ receivers with no case. I was wearing a very fashionable tie with reflective highlights created by thin metal threads. As I leaned over the set to look into the fault, I got an almighty whack on the back of my neck. It took a few moments to realise my tie had touched the EHT and the metal thread carried the voltage to the thinnest insulation – the back of my neck.

Please let me know if you would like to be a member of the HRSA and I will send information to you.

Kevin Poulter, Vice President, HRSA. SC

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In the past we heard a lot about "peak oil" and how the world would soon run out of oil. That is not going to happen for many years, if ever, and one the main reasons is the use of directional drilling. We asked Dr David Maddison to take a look at the topic and this is his report.

The big energy breakthrough:

Horizontal drilling for oil

Directional drilling, also known as slant drilling, is a technology which gives the ability to drill a hole into the ground in any desired direction (bearing) and angle, toward a predetermined location. It is widely used for oil and gas production, for "Surface in Seam" (where a well is drilled horizontally into a coal or shale seam to extract gas) and for underground utility cable or pipe installation.

In the past, oil wells were drilled over easily-accessible deposits. Early prospectors did not really know what to look for in terms of geological formations, so they would drill wells near places such as natural oil seeps.

As knowledge improved, prospectors could look for certain types of geology known to be associated with oil deposits. Beyond that, the development of remote sensing technologies which detected magnetic, gravitational and seismic properties improved the ability to find deposits at greater depth.

The only sure way to know if there is oil or gas is to drill a hole – but modern technology has improved the chances of finding oil from around 10% in early times to about 50% today.

One of the most significant historical incidents involving directional drilling was when Iraq accused Kuwait of stealing its oil via this method. This resulted in Iraq occupying Kuwait and subsequently led to the First Gulf War.

Directional drilling has specific applications as follows:

(a) Multiple wells from a single location

In the case of an off-shore drilling platform, directional drilling enables multiple wells to be drilled from a fixed location, saving the huge expense of moving the platform or building another. Many oil fields would not be economic without this capability.

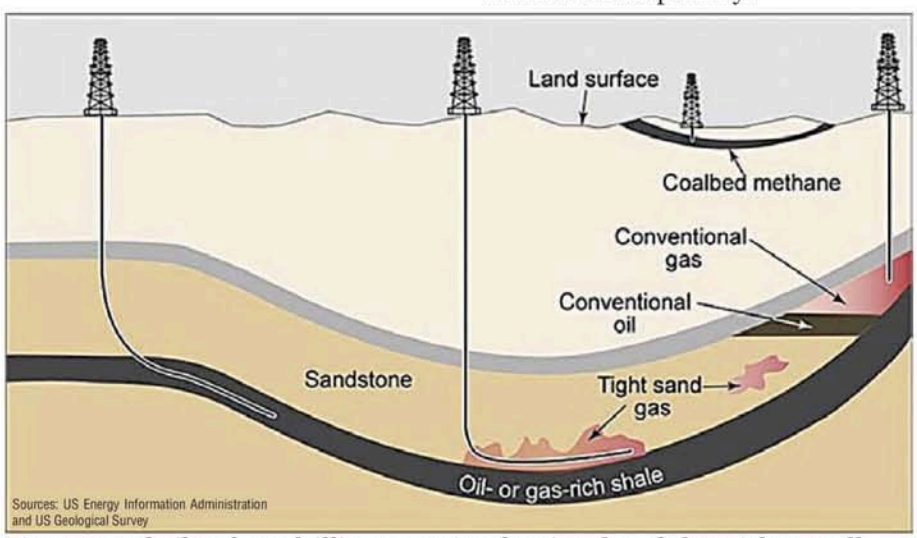


Fig.1: several oil and gas drilling scenarios showing, from left to right, a well that has been drilled vertically and then steered into a seam of hydrocarbon rich shale; a well that has been steered to intersect gas deposits within sand; a conventional vertical well to extract coal bed methane and on the far right a traditional oil and and gas well drilled vertically.

(b) Lack of suitable surface location for a drilling platform

An oil or gas deposit may lie beneath a town, city or a mountain or some other area unsuitable for a drilling platform.

Another example is offshore deposits which can be accessed from an onshore drilling rig where the deposit is relatively close to shore.

One example of drilling and recovery of oil from

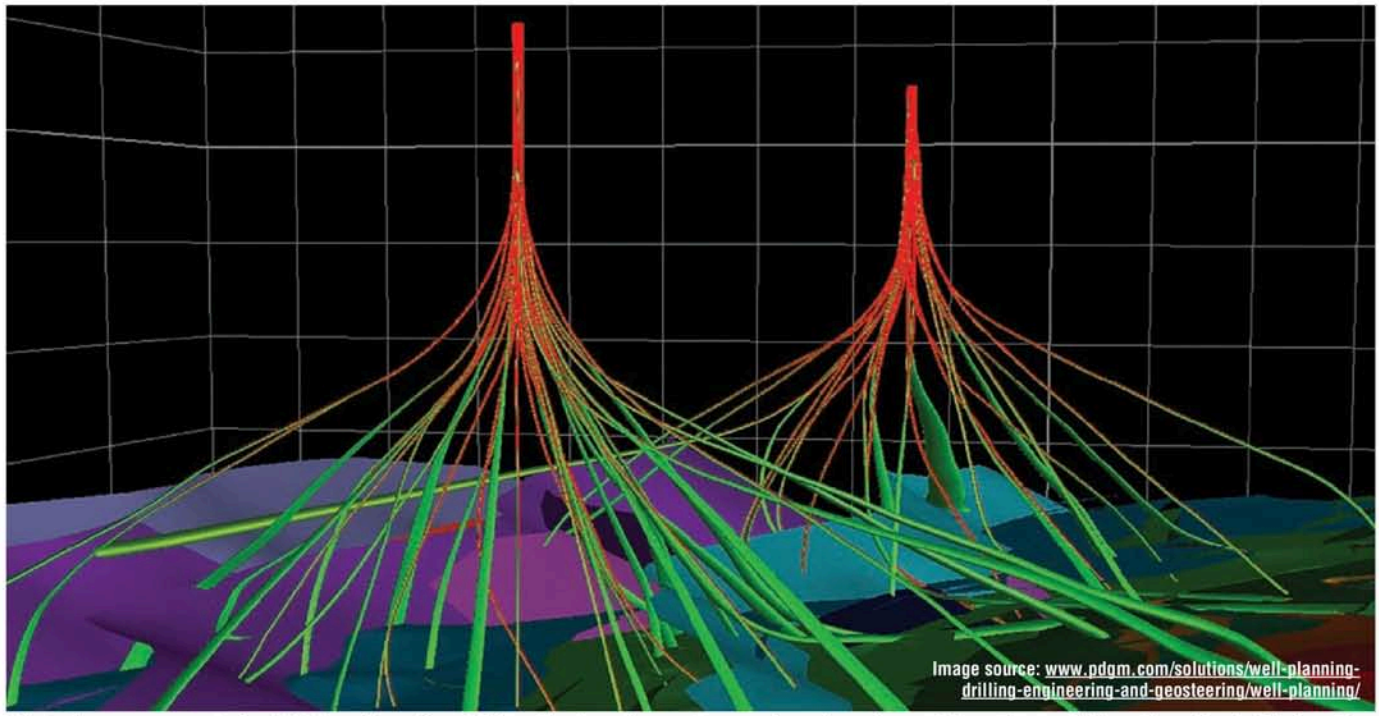


Fig.2: image generated with Paradigm Sysdrill well planning software showing planned locations of directionally drilled wells.

beneath a city is in the Beverly Hills Oil Field, part of the City of Los Angeles (see Fig.3 below).

(c) Drilling around obstructions

This is known as side-tracking. The directional drilling technique is used to drill around an obstruction in a well, such as a broken-off string of pipe or a drill bit. (Such pieces of debris are known as "fish".) Side-tracking can also be used to invigorate an old dry well by using part of the existing well and then side-tracking out of the original well casing to access possible untapped deposits.

(d) Drilling in heavily faulted rock formations

Heavily faulted rock formations can cause deflection of a vertical well during drilling. Also, a fault might slip, breaking the drill pipe. Directional drilling allows a better and safer approach angle to the deposit.

(e) Intersecting multiple deposits with a single well

In some cases it might be most economical to have a single well intersect multiple hydrocarbon deposits. This saves having to drill multiple wells.

(f) Drilling in an area of salt domes

Oil deposits are often associated with salt domes but drilling through a salt dome can be problematic. A well can be drilled in such a way as to avoid going through such domes.

(g) Drilling relief wells

Relief wells are often required to kill an oil or gas well that has "blown out". A blow-out is an uncontrolled flow of gas, oil or other well fluids from the well.

A nearby well is drilled to intercept or pass close to the bottom of the blown well and a special high density "kill fluid" is then injected to block the blowing well.

(h) Straightening a crooked well

A conventionally drilled vertical well might drift off course. Directional drilling techniques can be used to re-drill the well from the point of deviation, to realign it to the correct direction.

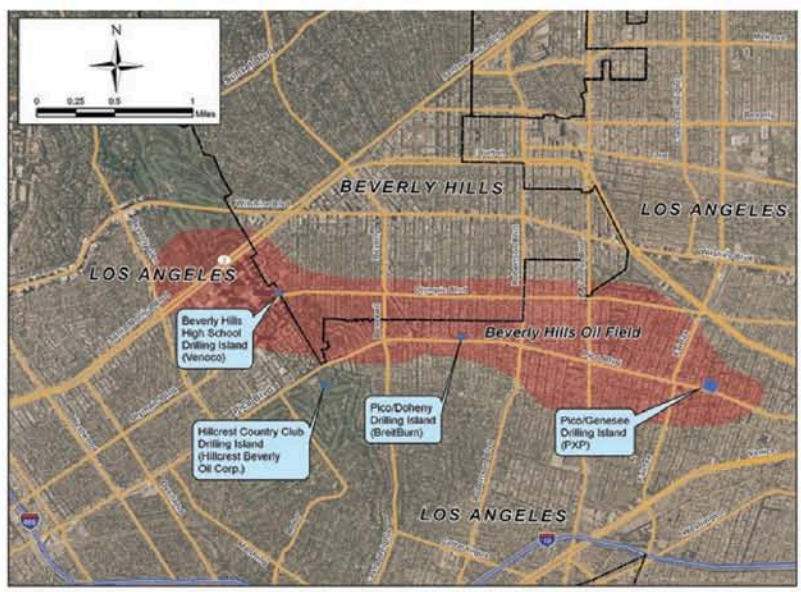


Fig.3: the Beverly Hills Oil Field is providing oil from a most unexpected location. Oil recovery is via directional drilling from four "drilling islands", hidden away beneath structures designed to disguise them.

(i) Recovery of coal seam or shale gas or oil

Huge quantities of gas and oil are now being extracted by horizontally drilling through coal, shale or oil-bearing seams. For an example of such drilling see Fig.6.

(j) Utility cables and pipes

Directional drilling techniques can also be used to install utility cables and

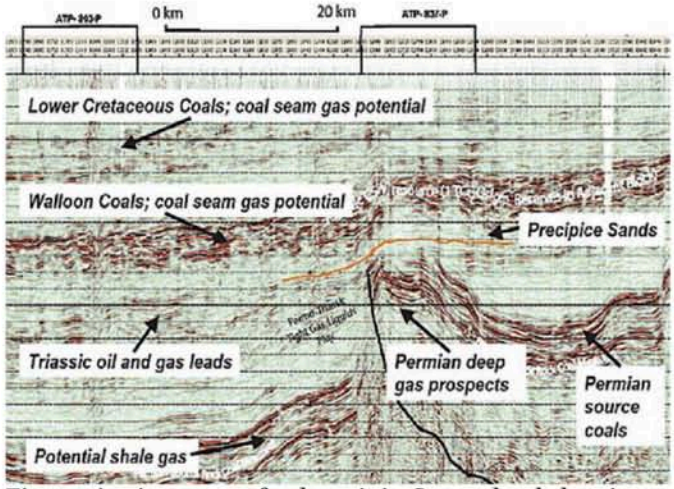


Fig.4: seismic survey of a deposit in Queensland showing a variety of possible oil, gas and coal deposits, demonstrating the great detail that can be produced describing structures within the Earth. Directional drilling technology can ensure that no economically recoverable deposit is inaccesible.

pipes. One application is to run these utilities under a river, thus saving the cost of a bridge; or running utilities under roads and footpaths without having to excavate. Naturally, one must check plans for existing services or detect existing services with special equipment. Many cables for the National Broadband Network (NBN) are being installed by this method.

Components of a drilling rig

The drilling rig imparts rotary motion to a drill string. It contains pumps to circulate drilling fluid or "mud" to facilitate the drilling process and has equipment to add or remove sections of pipe to or from the drill string.

The drill string comprises the components of the drill pipe, transition pipe and the bottom hole assembly. The bottom hole assembly comprises a drill bit, drill collars which are heavy thick walled tubes for applying extra weight to the drill bit, components such as down-hole motors or a rotary steerable assembly and various sensor packages.

Transition pipe makes a flexible connection between the drill collars and drill pipe. Drill pipe is hollow tubing which compromises the majority of the length of the drill string.

Fig.6: plan of horizontal drilling into gas bearing shale formation around Glenfarne in Ireland. Each set of wells has a common origin at a drilling pad indicated by a small red rectangle. Note the 1km scale marker indicating the massive scale of the horizontal drilling.

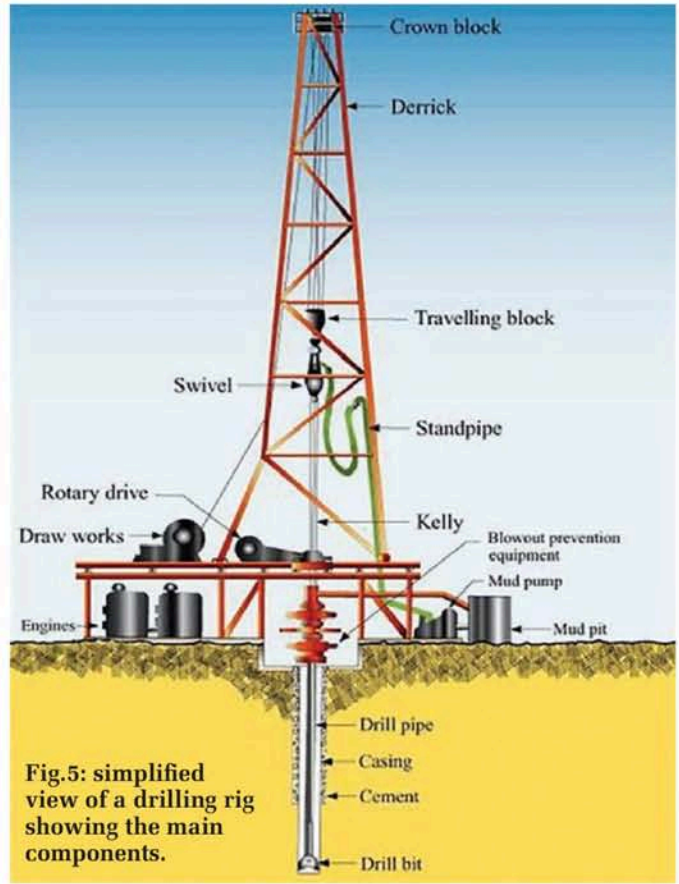


Fig.5: simplified view of a drilling rig showing the main components.

How is the drill steered?

There are several ways in which a drill can be "steered" to a desired direction and angle using "deflection tools". The basic principle involves applying side-force to the drilling bit, causing it to deviate from its straight line course.

The most common tools for directional deviation are steerable motor assemblies and rotary steerable systems which are placed at the end of the drill string. Other systems

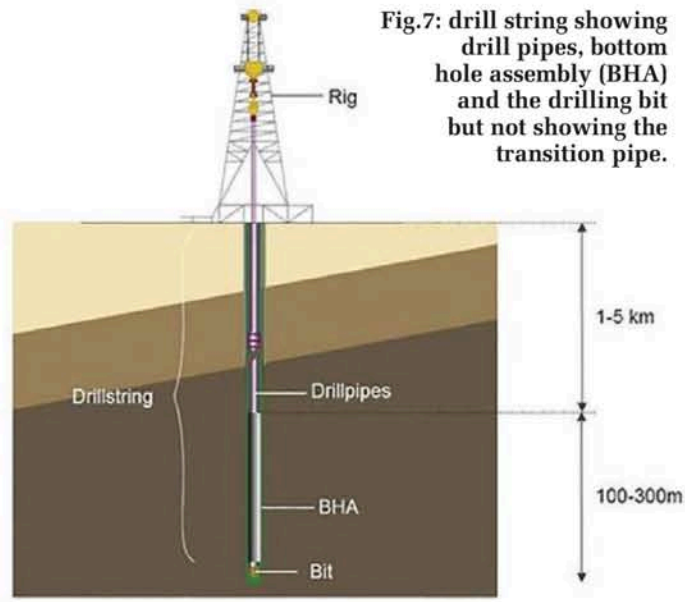


Fig.7: drill string showing drill pipes, bottom hole assembly (BHA) and the drilling bit but not showing the transition pipe.

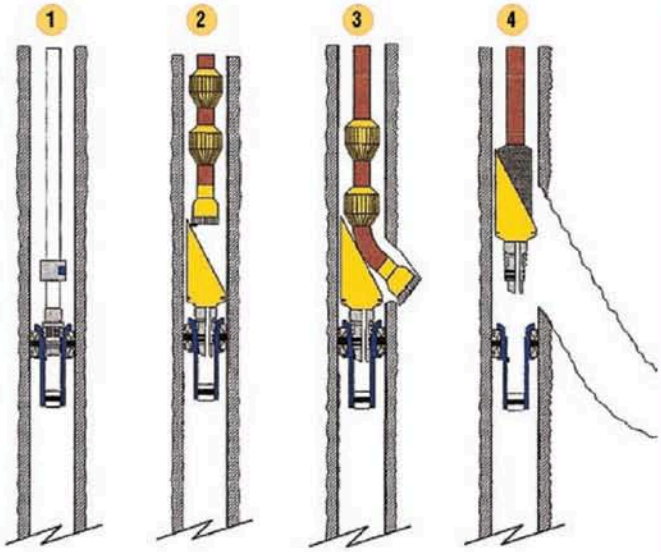


Fig.8: a whipstock. It is like a wedge placed in an existing bore hole that forces a special drilling bit to deviate off into unbored rock. The steps are as follows: 1) A packer is placed in the borehole at the desired location. 2) The whipstock is oriented to the desired angle. 3) A hole is milled through the side of the existing borehole. The tool can bend because of a flexible joint. 4) The whipstock is retrieved.

in use are whip stocks to sidetrack out of existing cased (lined) bore holes and jetting systems.

A whip stock is like a wedge placed down an existing borehole to apply lateral force on a special drill assembly, causing it to deviate through the side of the bore (see Fig.8).

Another method is to have a drill bit with a jet on it which cuts out a pocket of material using high pressure hydraulic fluid in the direction of desired travel. This is mainly of use in softer rock formations.

There are two more complex methods of directional drilling. One is a so-called steerable motor assembly and the other involves an assembly at the end of the drill train that can exert force on one side of the borehole to steer the bit, a so-called rotary steerable system.

Steerable motor assmblies

A steerable motor assembly contains a motor at the end of the drill string which is attached to a "bent-sub", a relatively short length of pipe that is at a slightly different angle to the rest of the drill pipe. Under normal circumstances of straight drilling, the entire drill string (comprising the drill pipe, the bent-sub and drill bit plus any electronics packages) is rotated as for a conventional drilling operation. The bend in the pipe does not affect anything as forces are applied evenly and the bore is cut in a straight line.

The motor is not electrical but is driven by high pressure

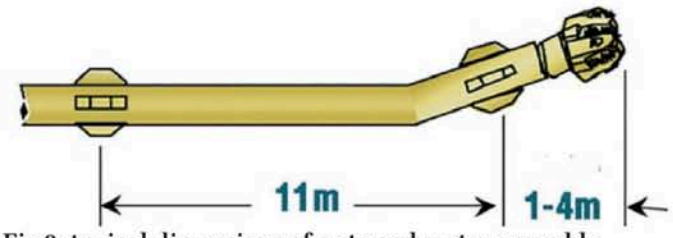


Fig.9: typical dimensions of a steered motor assembly.

History of Directional Drilling

Apart from drills accidentally deviating from the vertical (or possibly deliberately deviating from the vertical to steal someone else's oil!) one of the first legitimate applications of directional drilling was to relieve pressure on a well that was undergoing and uncontrollable fire in Texas.

A slanted well was drilled into which water was pumped which extinguished the fire at the wild well. This saved the oil field.

This work appeared on pages 40, 41 and 117 in the May 1934 issue of Popular Science Monthly. You can read it yourself at Google Books: https://books.google.com.au/books?id=wygDAAAMBAJ&lpg=PP1&pg=PA40#v=onepage&q&f=false

The article stated "Only a handful of men in the world have the strange power to make a bit, rotating a mile below ground at the end of a steel drill pipe, snake its way in a curve or around a dog-leg angle, to reach a desired objective."

The method used to deviate the drill was with a whipstock, (see Fig.8 at left).

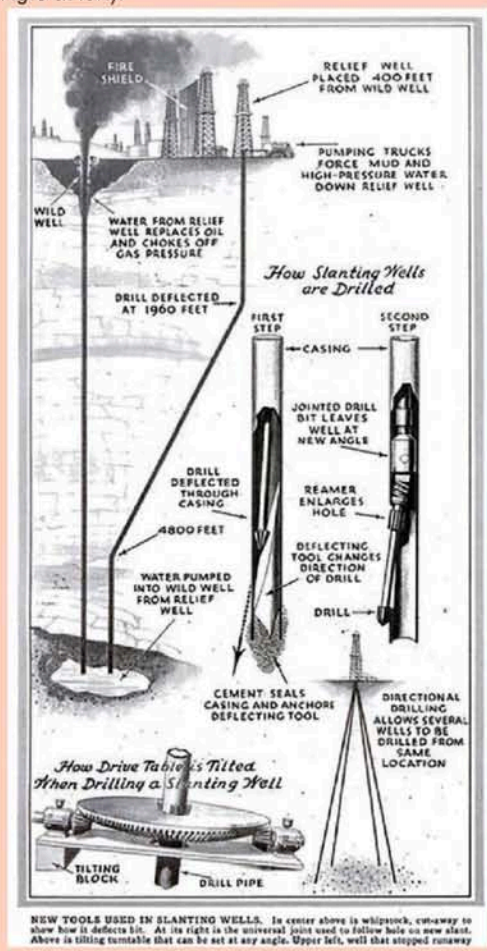


Illustration from 1934 "Popular Science" article about how directional drilling was used to put out a major oil well fire.

The next major development in directional drilling came in the 1970s with the development of the steerable motor assembly. Beyond that, rotary steerable systems were developed in the 1990s but were still considered an exotic technology until the 2000s.

The massive increase in computer power and remote sensing technology has since enabled extremely detailed maps of subsurface terrain. Computer power also allows the planning and the steering of the bore holes in any desired direction.

How much oil is left in the world?

This is a commonly asked question, especially since the predictions of the date of Peak Oil (the time of maximum extraction of oil is reached after which it declines) keeps getting pushed back and has done so since 1919, when the chief geologist of the US Geological Survey predicted peak production of US oil would be reached within a few years.

That's not to say that the time won't come, but we just keep finding more oil and have also started utilising unconventional sources such as tar sands.

In 1981 world consumption of oil was 60 million barrels per day and proven reserves were 700 billion barrels. On this basis it was predicted the world would be out of oil by December 2013.

By then, global production of oil was 46% higher than in 1981 and proven reserves were one trillion barrels greater. Today's current prediction, by BP, is that current proven reserves form around another 53 years supply.

The 53 year prediction is based on the concept of proven reserves which are what companies believe they can extract out of the ground at current prices with current technology and still make a profit.

As prices rise, formerly uneconomic reserves may become profitable or new technology (such as directional drilling) might make otherwise uneconomic reserves economic to recover. New discoveries will also be made. Actual proven reserves are a small proportion of the the oil left in the ground.

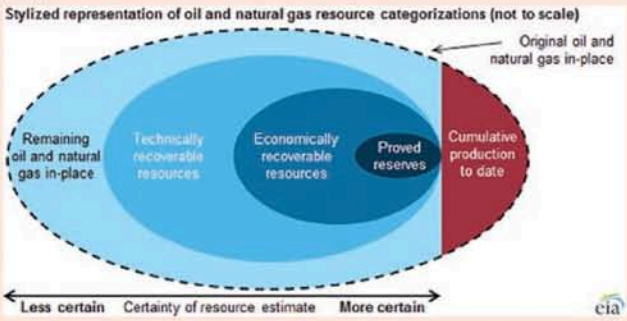


Diagram from the US Energy Information Administration showing the small proportion of proven reserves compared to the total amount of oil left. As prices rise or technology improves more oil becomes available.

"mud" forced through a spiral-shaped cavity or stator in which resides a matching rotor. There is a continuous seal along the matching edges of the stator and rotor and when mud is forced through the cavity, the rotor turns, causing the drill bit to rotate (see Fig.11).

This type of motor is known as a mud motor or progressive cavity positive displacement pump. Another type of mud motor uses a turbine instead of a rotor.

When a change in direction is required, the drill string is stopped from rotating but mud continues to flow through the mud motor. As there is a bend in the pipe and the whole pipe is no longer rotating, the cut will be in the direction of the bend. This operation when the drill string is not rotating is known as "sliding".

The key to this operation is knowing the way the bend is oriented since obviously it has to be steered toward a required direction. This is determined by "measurement while drilling" instrumentation located behind the drill bit, such as accelerometers, magnetometers and other instruments. Such instrumentation will be discussed later.

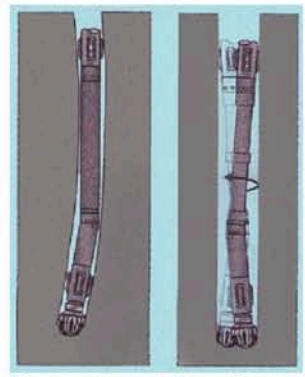


Fig.10: the two processes involved when directional drilling using a steerable motor assembly. On the left the drill string is stationary and the mud motor rotates the drill bit during the "sliding" process. On the right, the entire drill string rotates and the well is drilled in a straight line. Due to the bend in the pipe, the bore will be greater than the diameter of the drill bit. Note that the angle of the bend can be adjusted as circumstances dictate. Image from Deepak Choudhary's blog at http://directional-drilling.blogspot.com.au/

Rotary steerable systems

Unlike a steerable motor assembly, the drill string of a rotary steerable system constantly rotates even during steering operations and there is no bent-sub (length of pipe with a bend in it). Instead, there is a series of typically three pads around the circumference of a motor assembly which, under computer control, move in and out in rapid succession at a particular point in the drill string rotation. This exerts a sideways force at one point on the bore hole to force a change in the drilling direction. During straight drilling these pads are retracted.

As an alternative to separate pads, elliptical rings are used in some systems which are rotated to apply force on a particular side of the bore hole.

There is also the hybrid Schlumberger PowerDrive Archer rotary steerable system that has a motor within it thus giving advantages of both a steerable motor assembly and a rotary steerable system.

Steerable motor assemblies versus rotary steerable systems

Steerable motor assemblies are older technology than rotary steerable systems but nevertheless are reliable and in many cases more economical to use. However, rotary steerable systems can be used to drill wells which would be extremely difficult or impossible with a steerable motor assembly.

A key advantage of rotary steerable systems is the fact that the entire drill string turns at all times which prevents the possibility of the string becoming stuck against the borehole wall by friction, as could happen when using steerable motor assemblies during the process of sliding, when the only rotation is of the drill bit and mud motor but not the drill string.

In addition, this friction can result in less than the desired weight transfer to the drilling bit causing slower penetration rates. A further disadvantage of steerable motor assemblies is that during the process of sliding (when the drill string is stationary), drill cuttings tend to pack in around the bottom assembly. This is because there is no vortex created around a rotating drill string which tends

Fig.11: mud motor and drill bit assembly. The rotor assembly for the mud motor is visible at the left and the drill bit is on the right.

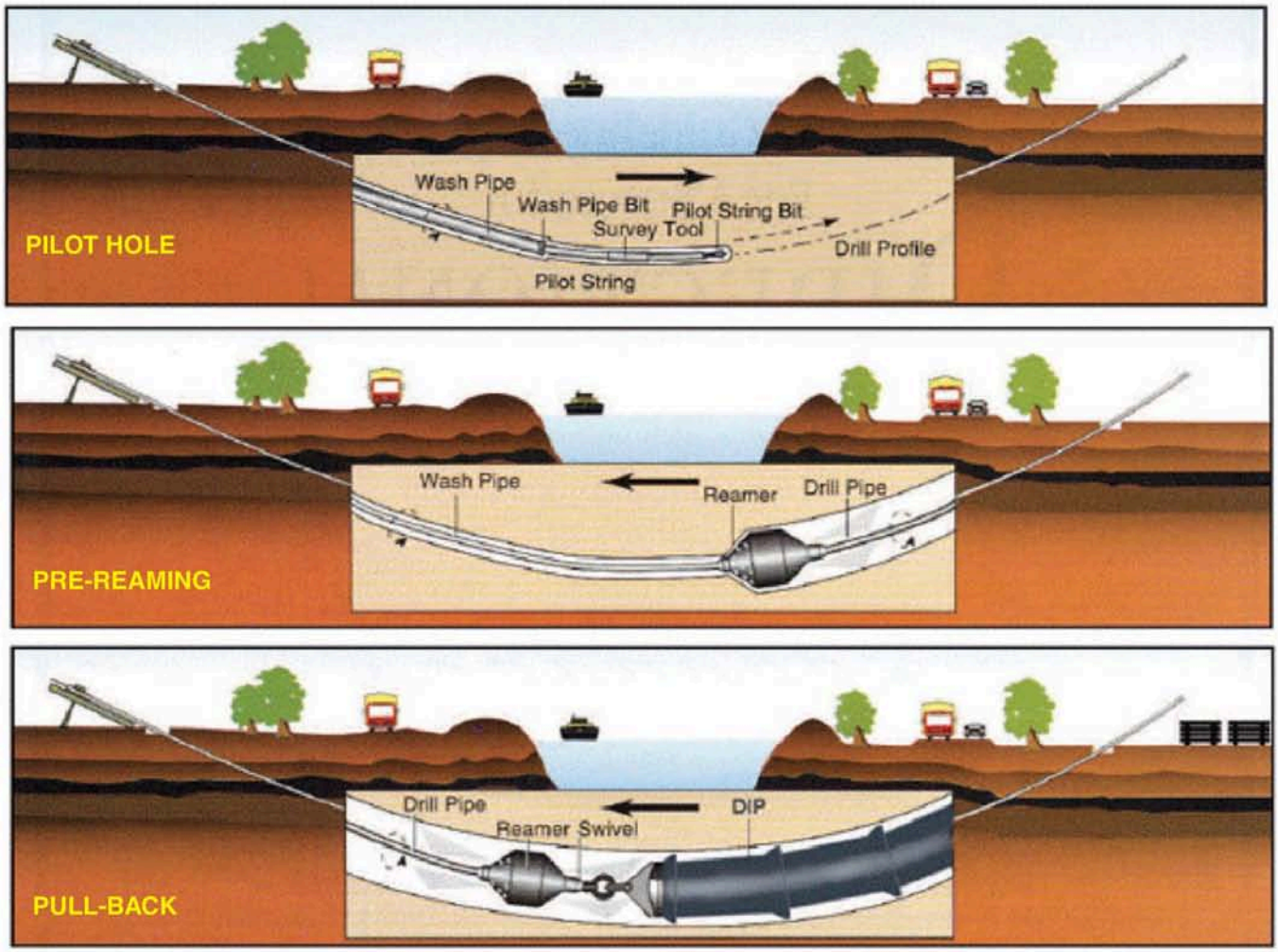
to keep the particles in suspension, making them easy to carry away to the surface.

There is also less drag with rotary steerable systems and a smoother hole which contributes to greater directional control. Logging-while-drilling, the process of obtaining bore hole data such as direction during the drilling process is also possible with this system. Higher accuracy is also a feature, enabling extremely small target zones to be reached such as in a layer that is only 45cm thick.

While rotary steerable systems have many advantages, one disadvantage is their cost. If precise directional control is not needed then a steerable motor assembly would be the preferred choice. Also, the rotation of the rotary steerable system is generally dependent on the drilling rig as they generally do not have their own motor, unlike steerable motor assemblies, so possibly a higher performance drilling rig would be required than with a steerable motor assembly.

The Weatherford Revolution® rotary steerable system.

There is also a more limited range of drilling bits available and much greater mechanical and electronic complexity. If a rotary steerable system is lost down a bore hole as happens from time to time, its replacement could cost over US$1



Method for trenchless installation of pipe under a river using directional boring. First a pilot hole is drilled and steered in the desired direction, then a reamer is pulled through that pilot hole from the opposite direction to expand the diameter of the hole and then the pipe is pulled through. Photo at left shows the horizontal boring machine and at right a length of pipe is prepared for the pull-back process.

Some videos on directional drilling

"Horizontal Directional Drilling / Boring (HDD): How the Drill Bit is Steered" https://youtu.be/cl8BBoCV7gU
"Directional Drilling 3D Animation.avi" (silent video) https://youtu.be/raTMsTpD3Pg
"Complete directional drilling operation" (silent video) https://youtu.be/tUxkx48HRIo
"Horizontal Directional Drilling - how it works" https://youtu.be/ufYMgHa0d18 This video shows the installation of an underground pipeline.
"Horizontal Directional Drilling - Pullback 48" Steel Gas Pipe" https://youtu.be/o-1kBFJLXSY
"Horizontal Directional Drilling, The Next Generation (HDB)" https://youtu.be/zr6pgRv6RDo
"Geo-Pilot® Rotary Steerable System from Halliburton" https://youtu.be/uVrw3InxPyc
"The Revolution Rotary-Steerable System - How It Works" https://youtu.be/9TEyYRAu2Uk

million compared with an average replacement cost of a steerable motor assembly of US$168,000.

Bore hole data

It is important to measure various parameters to do with the drill string and the rock formations through which the well is being bored. Some measurement systems work in real time and others require drilling to be stopped while a probe is lowered down the hole.

The instruments have to be extremely rugged and have to withstand temperatures up to 175°C, pressure up to 170MPa (25,000 psi) and 500G acceleration for 0.5ms. Power is supplied to the measurement system either by non-rechargeable lithium thionyl chloride batteries or a turbine and alternator system driven by the flow of the drilling mud.

There are two general categories of real-time measurements. Both require sensor instrumentation which is part of the bottom hole assembly.

Note that in some cases the sensor packages transmit some data while other data is recorded in memory and analysed when the bottom hole assembly is bought to the surface, due to the limited data rate available with some data transmission methods.

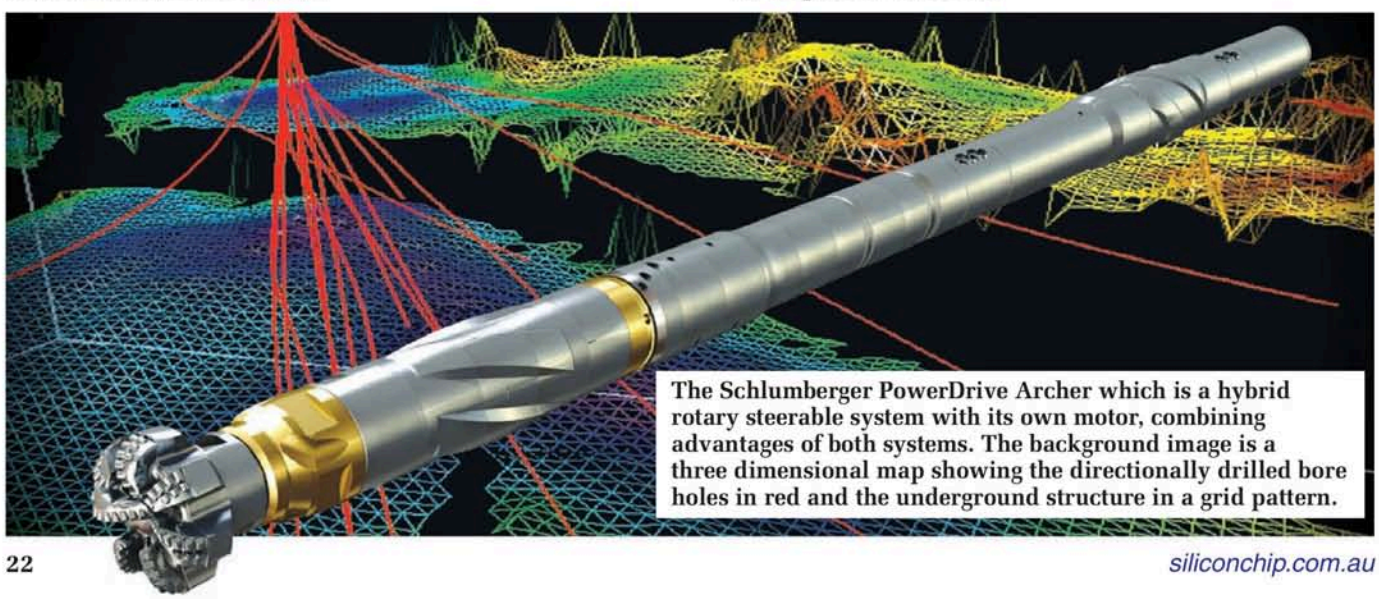
The Halliburton Geo-Pilot Dirigo rotary steerable system.

The first category is called ***measurement while drilling*** and relates to drilling mechanics and survey of the position of the drilling bit. Measurements include the inclination and direction of the drill bit, rotational speed, vibration of the drill string, temperature, torque on the drill bit, weight on drill bit and mud flow rate.

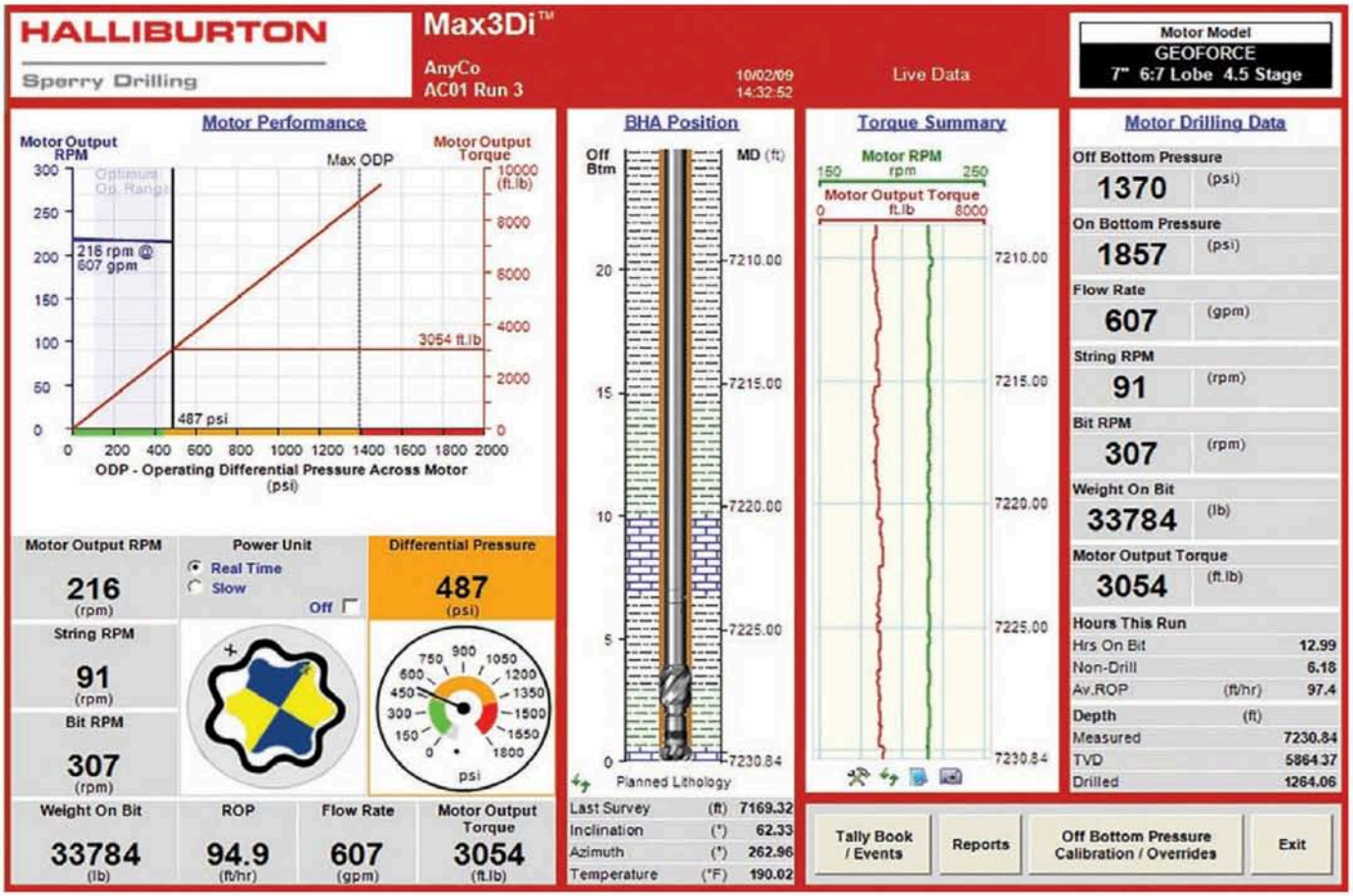
The second category is called ***logging while drilling*** and relates to properties of the rock formation being drilled. Measurements made include rock density and porosity, electrical resistivity. acoustic properties, magnetic resonance and formation pressure.

Logging while drilling enables the following measurements to be made, including:

- Gamma radiation from the rock;
- Density of rock and photoelectric index;
- Neutron porosity to indicate hydrogen content in a reservoir;
- Bore size and shape;
- Electrical resistivity of rock to help distinguish between formations containing salty water and hydrocarbons;
- Sonic logging to measure the ability of the bore hole to transmit sonic waves;
- Bore hole imaging;
- Testing and sampling of rock formation;
- Nuclear magnetic resonance to test a formation's porosity and permeability and
- Seismic measurements while drilling to determine optimal path of bore hole.



The Schlumberger PowerDrive Archer which is a hybrid rotary steerable system with its own motor, combining advantages of both systems. The background image is a three dimensional map showing the directionally drilled bore holes in red and the underground structure in a grid pattern.



Max3Di™ Drilling optimisation software that displays various drilling data sourced both at the surface and from the bore hole during the measurement while drilling process.

Mud-pulse telemetry

Several methods are used to transmit data from the bottom hole assembly instrument packages to the surface.

Mud pulse telemetry involves encoding data in the form of a modulated pressure pulse in the drilling mud which is measured at the surface and then decoded. The pressure pulse is generated with a valve in an instrument package near the drill head to momentarily restrict the flow of drilling mud. It can be in the form of either a positive or negative pulse, depending upon conditions inside the borehole.

There is also a form of mud pulse telemetry involving encoding data on a continuous wave via sinusoidal pressure variations. Data rates of up to 40 bits per second are possible but this diminishes with distance and can drop to as little as 1.5 bits per second at a well bore length of 12,200 metres.

Electromagnetic telemetry involves sending either a magnetic or electrical pulse from the drilling tool which is detected on the surface. The data rate is higher than for mud pulse telemetry but it does have depth limitations and a signal may be undetectable at depths beyond 1000 metres or in certain rock formations.

High speed data transmission can be effected by using wired drill pipe. Connections are made between different sections of pipe via electromagnetic induction through an inductive loop. Very high data rates of up to 1 Mbit per second or more are possible. In addition, it enables a local area network to be established with the ability to make various instrument and tools on the drill string individually addressable.

The technology was first deployed in 2006 and is known by the trade name of IntelliPipe for the physical pipe and IntelliServ for the network architecture.

Utility cabling and pipes

Apart from its use in oil and gas drilling, directional drilling or more correctly, directional boring (also known as horizontal directional drilling) is used to install utility cables, conduits and pipelines without having to dig trenches and with minimal environmental impact. Of course, before proceeding it is vitally important to do a site survey first to determine the location of other underground services.

Unlike directional drilling in the oil and gas industry

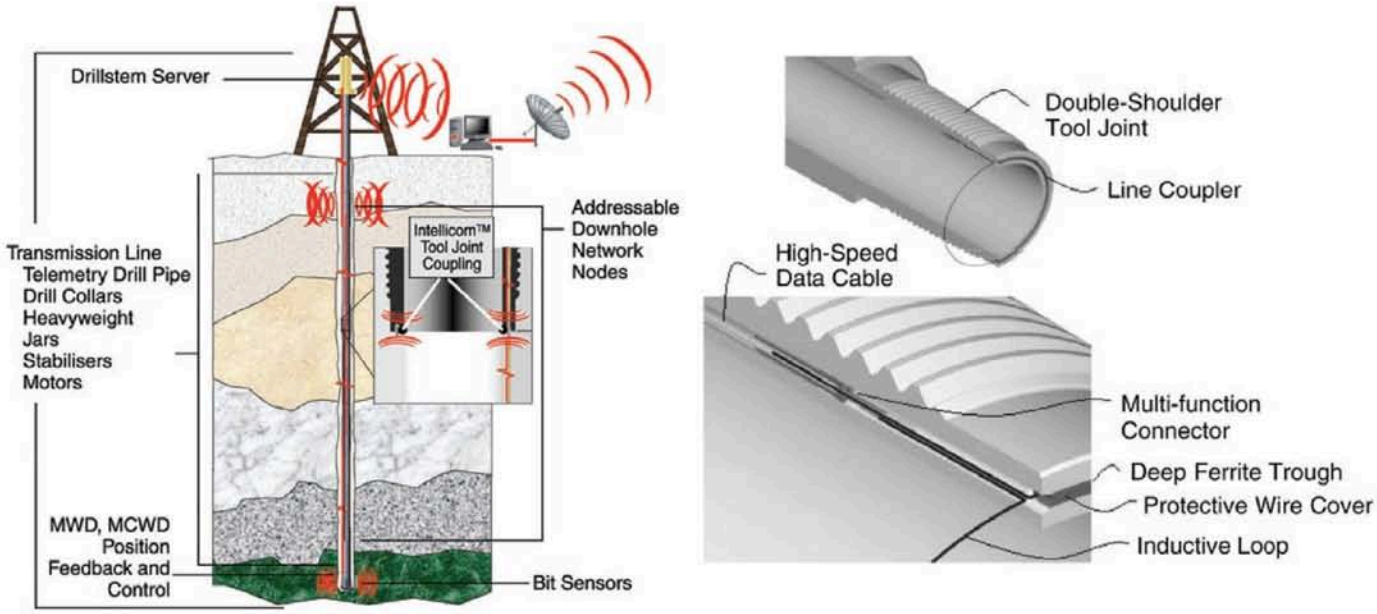
A look inside an oil well

Here is a fascinating collection of video clips from a camera sent down various oil wells to look at different problems. Note that the term "fish" used in the video refers to undesired debris in the well such as broken pipe.

In these videos the wells have been shut down (sealed off) to reduce the flow of gas and oil to enable inspection to take place.

"Oil Well Downhole Camera Video (1/2)"
https://youtu.be/ZzDrheWDhGw

"Oil Well Downhole Camera Video (2/2)"
https://youtu.be/5diKdBZ8EOI



Intellipipe® concept for high speed data transmission. A data connection is made across sections of pipe via electromagnetic induction across the pipe joint while a cable runs within the section of pipe. The concept also establishes a local area network within the drillstring enabling individual sensors and tools to be addressed. MWD stands for measurement while drilling.

where the initial direction of the bore is roughly in the vertical direction, directional boring is closer to horizontal. A bore hole is initiated at a shallow angle and then steered into a more horizontal position.

Typically, a tapered cutting bit is used and it provides the steering mechanism. When a direction change is required the drill string is stopped from rotating and the taper oriented to move the drill in the direction required. Then the drill string is thrust forward and rotation of the drill string begins.

Jetting or a steering process similar to the sliding of a mud motor can also be used. The choice of a tapered head, jetting or mud motor depends on the nature of the subsurface structure.

It is obviously important to know the location of the drill head and this is done via one of four methods.

In the ***walk over locating system,*** a transmitter located at the bore head electromagnetically transmits data to the surface concerning angle, rotation and direction data and this is received by a hand held receiver over the general vicinity of the bore head. The received data is then used by the boring machine operator to make any corrections required.

Magnetic guidance is a method utilising magnetometers and accelerometers at the drill head to calculate the directional heading and location of the drill head. In some urban environments there is a lot of magnetic interference and so an artificial magnetic field is generated at the surface.

A secondary system of location that can be used with magnetic guidance involves the use of a DC coil placed on the surface to generate ***a magnetic field which is sensed at the drill head***. Very high accuracy of location is possible with this method.

A ***gyroscope-based system*** is also available that works in real time and provides directional data to autonomously steer the drill head.

Pipes can be installed in a diameter range from 75mm to 2000mm and multiple smaller pipes or conduits can be installed at once during the pull back process. Pipes can be installed using smaller machines at a depth of up to 4.5m but this is a limitation of the surface tracking system. Larger machines can install pipes down to about 60m in depth. The length of pipe that can be installed ranges from around 120m to 4570m (maximum diameter and length figures are for a HERRENKNECHT HK600T machine).

A video of the directional boring process can be viewed at https://youtu.be/FQBVTlcl20c *"Prime Drilling - Horizontal directional Drilling explained"*.

Conclusion

Directional drilling enables oil and gas to be extracted from formations which would be unreachable or uneconomic by conventional drilling methods and enables more energy to be extracted from the earth to feed our energy hungry civilisation.

Directional boring enables conduits and pipes to be installed relatively inexpensively without needing to dig expensive trenches. SC

A Ditch Witch JT60 directional boring machine. The drill string is initially bored into ground at a shallow angle. In this case the drill string can be seen coming out to the left of the machine. Extra lengths of drill pipe visible on the machine are added as the boring progresses. Such machines are available in a wide range of sizes.

SAD

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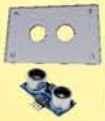
3mm lens, 25mm long leads.....**25c**
5mm lens, 25mm long leads.....**25c**
5mm lens, 15mm long leads.....**20c**



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Universal Temperature Alarm

By JOHN CLARKE

This compact alarm can be used to monitor the operating temperature of a whole range of devices. You could use it to monitor your tropical fish tank, your home brew, freezer, fridge, your hot water system or whatever. It can monitor temperatures in the range of -33° to 125° Celsius and provide an alarm when the temperature is above, below or not within a specified temperature range.

This project was originally developed with the specific intention of monitoring a tropical fish tank and to replace our Aquarium Temperature Alarm from the September 2006 issue of SILICON CHIP. Hence the "fishy" front panel in the photo above.

The PCB for that project is no longer available and so we decided to revise it and also provide an on-board piezo transducer as the audible alarm.

Having done that, it was quite obvious that the project has much wider applications and so we are presenting it as a Universal Temperature Alarm.

Harking back to the original application, if you're using it to monitor a tropical fish tank, you would normally set the upper temperature limit at 26°C and the lower limit at 24°C – quite a narrow band of temps to keep your fish happy and well.

If the temperature drifts outside this range, the piezo transducer will sound and one of the warning LEDs will light – red for hot, blue for cool.

On the other hand, for universal monitoring applications, you can set the upper temperature limit as high as 125°C or as low as -33°C; boiling or deep frozen; probably not all that good for fish (unless they're scaled, cleaned and waiting in the deep freezer. . . and the Universal Temperature Alarm can be used to monitor that as well!).

Features

- Small size
- Over temperature indication
- Under temperature indication
- Over and under temperature alarm
- Adjustable upper and lower temperature thresholds
- Easy calibration
- Selectable over and under temperature alarm options

The unit is housed in a small plastic case and is powered using a 9V to 12V DC plugpack or a 12V battery. A hand-made temperature probe connects to the alarm using a 3.5mm jack plug.

Circuit description

The circuit of Fig.1 employs six op amps and an LM335Z temperature sensor. While it may look complicated, only two op amp IC packages are involved and you can put it together easily in an hour or so.

Best of all, for those readers who find soldering small components a challenge, no surface mount components are used. (Do we hear a loud cheer?)

The six op amps are contained with an LMC6484AIN quad op amp package and an LMC6482AIN dual op amp. Both devices are rail-to-rail which means than their inputs and outputs can swing over the full supply voltage range, which in this case is 5V.

Three of the op amps (IC1a, IC1b and IC1c) are used as unity gain buffers and another (IC1d) as an oscillator for the alarm. And two op amps (IC2a and IC2b) make up a window comparator that is the heart of the circuit.

Temperature sensing is performed by an LM335Z, fed with current via a 2kΩ resistor from the 5V supply. It produces an output voltage that is directly proportional to temperature in Kelvin.

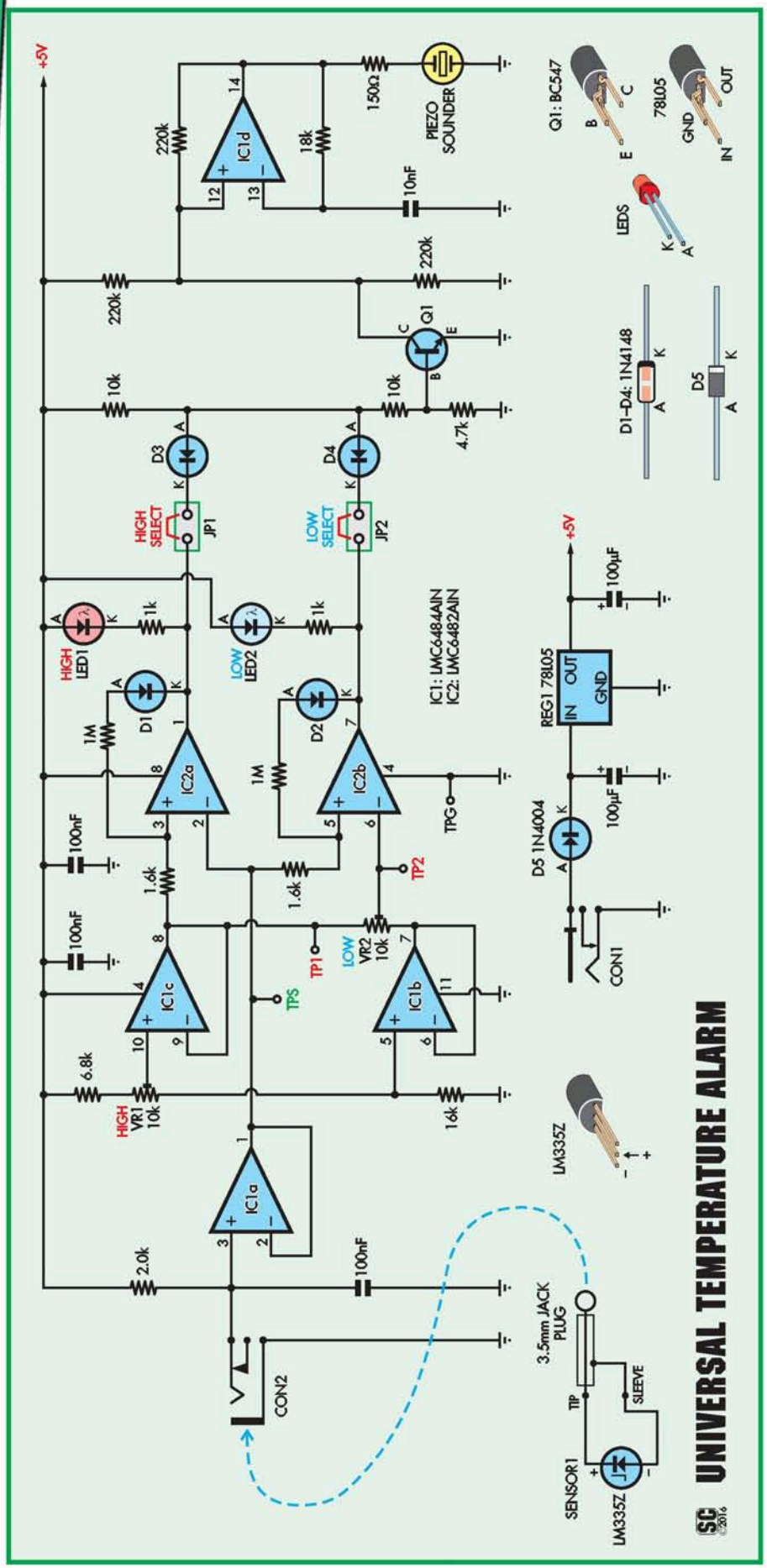
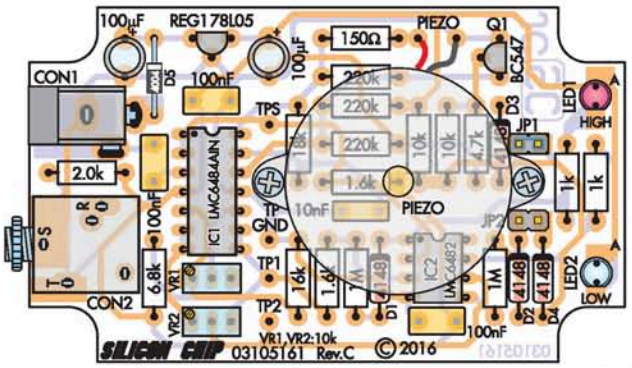


Fig.1: the circuit is based on a window comparator comprising op amps IC2a & IC2b with upper and lower thresholds set by trimpots VR1 & VR2. If the temperature sensor voltage is above or below the limits set by VR1 & VR2, the outputs of IC2a or IC2b will forward bias diodes D3 or D4 respectively and Q1 will be turned off, to allow the oscillator based on IC1d to drive the piezo transducer.



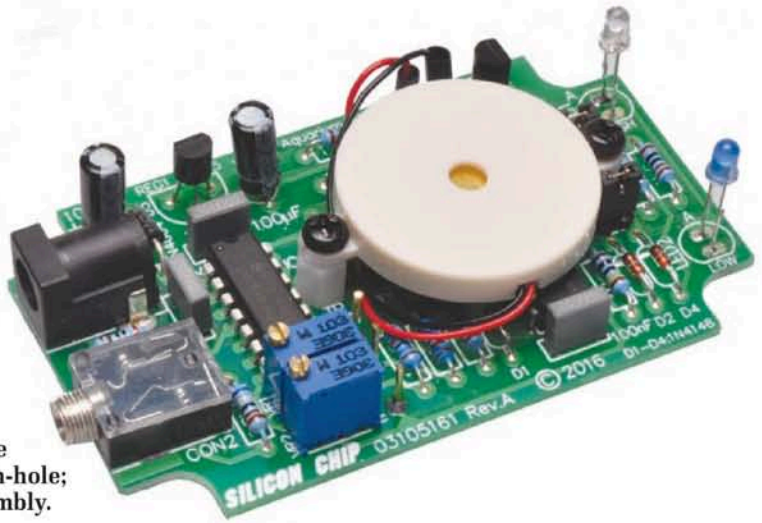


Fig.2: assemble all the small components onto the PCB before you mount the piezo transducer. All components are through-hole; no surface mount components have been used, for easy assembly.

Kelvin is the temperature scale that begins at absolute zero (the coldest temperature possible), equal to -273.15°C. Also note that it is never expressed as degrees Kelvin, or °K – it is simply K.

The sensor output is typically 10mV/K with the output at 0V at 0K. At 0°C (273K) output voltage is typically about 2.73V.

The sensor's output is filtered with a 100nF capacitor to remove any noise that could be picked up in the sensor leads. IC1a then buffers the sensor voltage so it provides a low impedance feed to the window comparator inputs of IC2a and IC2b.

Window comparator

What is a "window" comparator? Answer: it is pair of comparators which work together to sense whether a voltage is above a set limit (the upper comparator) or below the set limit (the lower comparator).

In our circuit, IC2a is the upper comparator and IC2b is the lower comparator. The buffered sensor voltage is applied to inverting input pin 2 of IC2a and non-inverting input pin 5 of IC2b.

Each of these op amps needs a reference voltage which is then compared with the buffered sensor voltage.

So we need two reference voltages, one for each comparator. IC1c buffers the voltage from the upper threshold trimpot VR1 which is connected between a 6.8kΩ resistor from the 5V supply and a 16kΩ resistor to the 0V supply. The resistors restrict VR1's wiper range to between about 2.4V and 3.96V. The maximum voltage corresponds to 123°C, while the lower voltage corresponds to -33°C.

Note that the LM335Z we used is only suitable for use up to 100°C. However, this wider range is included so that the alternative LM235Z, rated for up to 125°C, could be used if you wanted to.

The connection for the lower threshold trimpot VR2 is a little more complex.

Op amp IC1b buffers the voltage from the low side of VR1 and its output connects to the lower side of VR2 while its upper side connects to the output of IC1c (ie, the buffered VR1 output).

So VR2 provides the lower threshold adjustment which will always be below (or equal to) the upper threshold voltage.

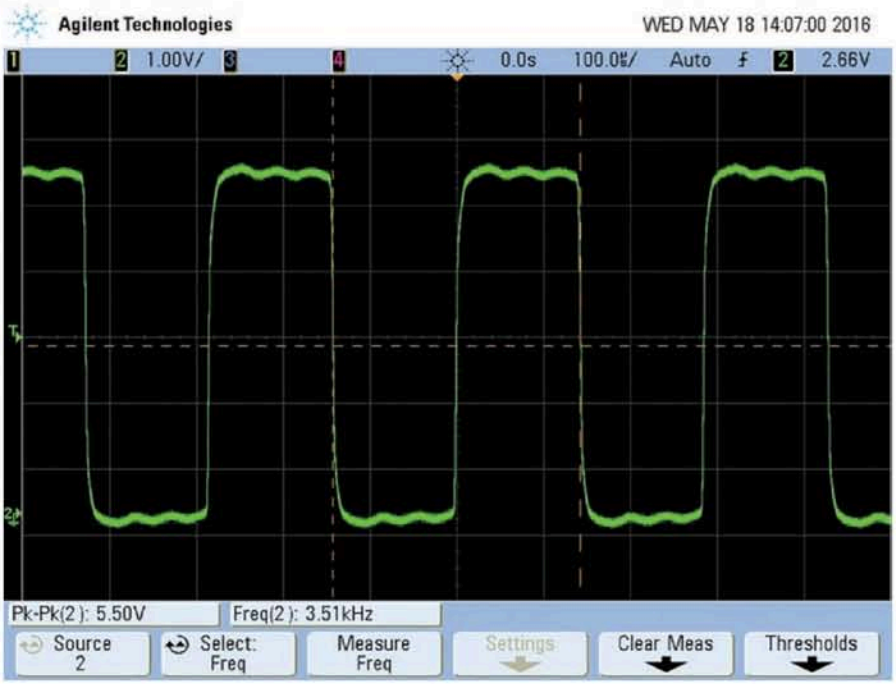
We have set up the circuit so that the lower threshold voltage can never be above the upper threshold voltage, because otherwise the window comparator would not operate correctly.

Both the window comparator outputs are high (ie, +5V) when the sensor voltage is between the upper and lower threshold voltage. This is the normal condition for which the alarm does not sound.

In this condition, diodes D3 and D4 are reversed biased when the op amp outputs are high (ie, when links JP1 and JP2 are connected).

So consider what happens when the monitored temperature goes above or below the specified range.

IC2a's output will go low (0V) when the sensor voltage goes above the threshold voltage set by VR1. Similarly, IC2b's output will go low



Scope1: this is the oscillator waveform produced at the output of IC1d. Despite the supply voltage from REG1 being very close to 5V (actually, 5.0372V) the square wave output has some ringing which increases the measured output swing to 5.5V peak-to-peak.

when the sensor voltage goes below the threshold voltage set by VR2. In the former case, D3 is forward biased and in the latter case, D4 is forward biased.

In each case, transistor Q1's base voltage will be pulled down and it will switch off, enabling the alarm signal provided by op amp IC1d to drive the piezo transducer.

IC1d is connected as a Schmitt trigger oscillator, with its non-inverting input, pin 12, connected to three 220kΩ resistors. One resistor connects to the +5V supply, the second to 0V and the third to the op amp output.

The inverting input is connected to a 10nF capacitor that goes to 0V and to an 18kΩ resistor that connects to the op amp output. The 220kΩ resistors set the input bias and the hysteresis for the Schmitt trigger oscillator.

We'll come back to that point in a moment.

When power is applied, the 10nF capacitor at the inverting input, pin 13, is discharged, and therefore the inverting input is low and the output at pin 14 will be high. The 10nF capacitor then commences to charge via the 18kΩ resistor to just over 3.33V, which is the lower threshold set by the 220kΩ resistors.

At that point the circuit toggles so that the output at pin 14 goes low and 10nF capacitor discharges towards the lower threshold of 1.66V.

This cycle repeats while ever Q1 is off and the result is a square wave of approximately 3.5kHz at the output of IC1d, pin 14. This drives the piezo transducer.

Window comparator hysteresis

Both the comparators based on IC2a and IC2b incorporate a small amount of hysteresis, as mentioned above. This prevents the op amps from oscillating on and off at their respective threshold voltages.

For IC2a, the 1MΩ resistor and diode D1 pull the non-inverting input slightly lower when IC2a's output goes low, by about 4mV. The 1.6kΩ resistor to IC1c's output sets this voltage change.

This effectively shifts the upper threshold voltage detected by IC2a lower by 4mV. So the sensor voltage needs to drop by a further 4mV before the IC2a output will go high again.

For IC2b, the 1MΩ resistor and diode D2 pull the non-inverting input

Parts list – Universal Temperature Alarm

1 PCB coded 03105161, 78 x 47.6mm
1 UB5 translucent clear or blue case, 83 x 54 x 31mm
1 panel label, 76 x 48mm
1 30mm diameter piezo transducer (Jaycar AB-3440, Altronics S 6140)
1 2.1 or 2.5mm DC socket, PCB moutning (CON1)
1 3.5mm switched stereo jack socket (CON2)
1 3.5mm mono or stereo jack plug
2 M3 tapped 6mm spacers
2 M3 x 5mm machine screws
2 M3 x 5mm Nylon or Polycarbonate screws (or cut down longer threaded screws)
2 2-way pin headers (2.54mm pin spacing) (JP1,JP2)
2 jumper shunts
6 PC stakes
1 1m length single core shielded cable
1 35mm length of 2mm diameter heatshrink tubing
1 ball point pen casing for temperature probe
Aquarium rated silicone sealant (Selleys Glass Silicone or equivalent)

Semiconductors
1 LMC6484AIN quad CMOS op amp (IC1)
1 LMC6482AIN dual CMOS op amp (IC2)
1 78L05 5V regulator (REG1)*
1 BC547 NPN transistor (Q1)
1 LM335Z or LM235Z temperature sensor (SENSOR1)
4 1N4148 switching diodes (D1-D4)
1 1N4004 diode (D5)
1 3mm red high brightness LED (LED1)
1 3mm blue high brightness LED (LED2)

*** Variation in the 5V output of REG1 can cause an error of ±0.5°C over the typical range of indoor ambient temperatures. If better stability is required, you can substitute an LP2950.5 regulator, which has the same pinout.**

Capacitors
2 100µF 16V PC electrolytic
3 100nF 63V or 100V MKT polyester *(code 104 or 0.1)*
1 10nF 63V or 100V MKT polyester *(code 103 or 0.01)*

Resistors (0.25W, 1%)

2 1MΩ	3 220kΩ	1 18kΩ	1 16kΩ	2 10kΩ	1 6.8kΩ
1 4.7kΩ	1 2.0kΩ	2 1.6kΩ	2 1kΩ	1 150Ω	

2 10kΩ multiturn top adjust trimpots (VR1,VR2)

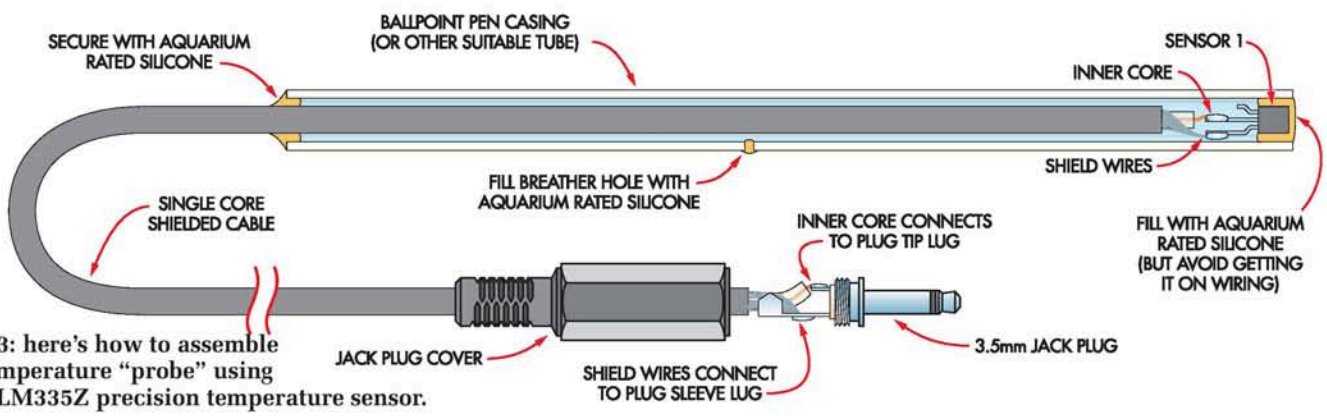


Fig.3: here's how to assemble a temperature "probe" using the LM335Z precision temperature sensor.

The completed Universal Temperature Alarm, shown here in its "aquarium" livery, along with the plug-in temperature probe made from the LM335Z temperature sensor, an old ballpoint pen case and some Aquarium-grade silicone sealant. The lead can be made significantly longer if your application calls for it. Inset bottom right is the business end of the probe, housed in sealant – just make sure you don't get any sealant on the sensor leads or wires.

lower when IC2b's output goes low by about 4mV. This shifts the sensor voltage lower by 4mV and the actual sensor voltage needs to increase by 4mV before the IC2a output can switch high again.

When the sensor voltage goes above the high threshold, this is indicated with LED1. For the sensor voltage below the low threshold, LED2 will light instead.

Power for the circuit can come from a 9V or 12V DC plugpack supply or 12V battery.

A 5V regulator (REG1) regulates the supply to provide a fixed voltage for the upper and lower threshold settings. The regulator includes 100µF bypass capacitors at its input and output for stability.

Construction

The Universal Temperature Alarm is entirely constructed on a double-sided PCB coded 03105161 and measuring 78 x 47.6mm.

The completed PCB is housed in a UB5 (83 x 54 x 31mm) plastic case. For effect, we used the semi-transparent blue case.

Fig.2 shows the PCB overlay. Begin construction by installing the resistors, using a DMM to check the value of each before inserting into the PCB. The resistor colour code table also shows the colour codes for each resistor value.

Diodes D1 to D5 can now be installed, taking care to orient correctly and note that D5 is a 1N4004 while the remaining diodes are 1N4148s.

IC1 and IC2 can be directly soldered in or IC sockets used. Take care to orient these with the correct polarity. REG1 and Q1 are soldered in now. Don't get them mixed up as these and the temperature sensor look similar, apart from their type markings

PC stakes can be used for the test points and for the piezo connection points.

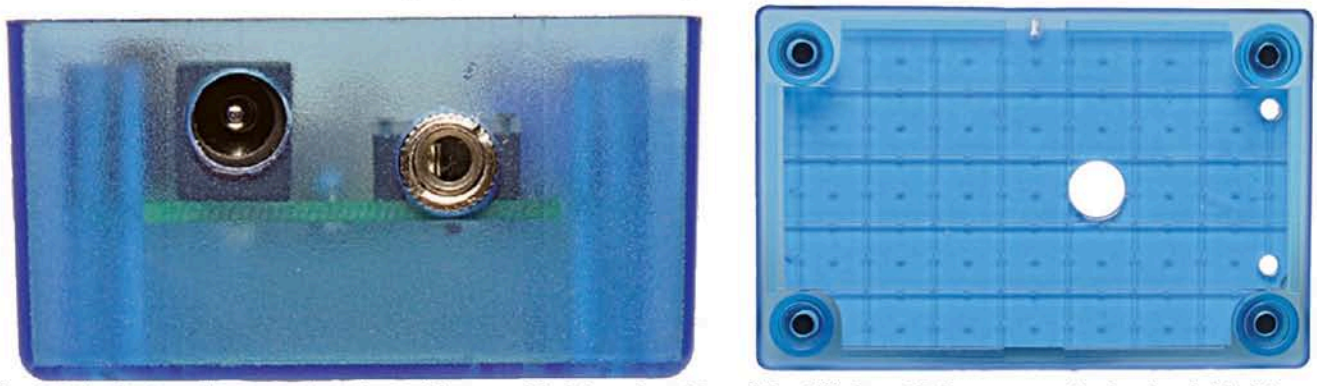
The two 100µF electrolytic capacitors need to be installed with the polarity shown and with the top of these no more than 13mm above the top edge of the PCB.

Install the 100nF and 10nF capacitors next. These can be positioned either way round. Then solder in the 2-way pin headers for JP1 and JP2 along with the cell holder.

Trimpots VR1 and VR2 can now be installed. These are oriented with their screw adjusters toward CON2 as shown.

LED1 and LED2 are mounted so the top of the LED lens is 16mm above the top surface of the PCB. Make sure the longer lead of each LED (the anode) is inserted in the 'A' position on the PCB.

The red LED is for LED1, the high



The PCB is designed to snap into the guides moulded into the sides of the jiffy box. Holes are required to be drilled in one end and the lid, as seen above.

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Table 2: SENSOR OUTPUT with respect to Kelvin and °C

°C	Kelvin (K) (Add 273.15 to °C)	LM335 output assuming 10mV/K
100	373.15	3.7315V
95	368.15	3.6815V
90	363.15	3.6315V
85	358.15	3.5815V
80	353.15	3.5315V
75	348.15	3.4815V
70	343.15	3.4315V
65	338.15	3.3815V
60	333.15	3.3315V
55	328.15	3.2815V
50	323.15	3.2315V
45	318.15	3.1815V
40	313.15	3.1315V
35	308.15	3.0815V
30	303.15	3.0315V
29	302.15	3.0215V
28	301.15	3.0115V
27	300.15	3.0015V
26	299.15	2.9915V
25	298.15	2.9815V
24	297.15	2.9715V
23	296.15	2.9615V
22	295.15	2.9515V
21	294.15	2.9415V
20	293.15	2.9315V
19	292.15	2.9215V
18	291.15	2.9115V
17	290.15	2.9015V
16	289.15	2.8915V
15	288.15	2.8815V
14	287.15	2.8715V
13	286.15	2.8615V
12	285.15	2.8515V
11	284.15	2.8415V
10	283.15	2.8315V
9	282.15	2.8215V
8	281.15	2.8115V
7	280.15	2.8015V
6	279.15	2.7915V
5	278.15	2.7815V
4	277.15	2.7715V
3	276.15	2.7615V
2	275.15	2.7515V
1	274.15	2.7415V
0	273.15	2.7315V

Use this table to set up your Universal Temperature Alarm. The areas highlighted are that of most interest to tropical af-fish-ionados; if you need temperatures not an even 5 or 10° above 30°, extrapolate.

Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	2	1MΩ	brown black green brown	brown black black yellow brown
❑	3	220kΩ	red red yellow brown	red red black orange brown
❑	1	18kΩ	brown grey orange brown	brown grey black red brown
❑	1	16kΩ	brown blue orange brown	brown blue black red brown
❑	2	10kΩ	brown black orange brown	brown black black red brown
❑	1	6.8kΩ	blue grey red brown	blue grey black brown brown
❑	1	4.7kΩ	red violet red brown	red violet black brown brown
❑	1	2.0kΩ	red black red brown	red black black brown brown
❑	1	1.6kΩ	brown blue red brown	brown blue black brown brown
❑	1	1kΩ	brown black red brown	brown black black brown brown
❑	1	150Ω	brown green brown brown	brown green black black brown

LED (marked on the PCB); similarly the blue LED (LED2) is for low.

If the LEDs you have are clear, it's easy to check if the LED is red or blue using the diode test on a multimeter. The LED should faintly glow to see the colour under test.

The piezo transducer is mounted off the PCB, supported on 6mm spacers and secured with M3 screws. Use the two Nylon or polycarbonate screws on the underside of the PCB so that there will be no possibility of shorting between tracks and pads.

If necessary, enlarge the mounting holes for the piezo transducer to 3mm to suit the screws. Wires can be soldered to the PC stakes marked 'piezo' on the PCB. Using PC stakes allows for short lengths of heatshrink tubing to be placed over the wires and PC stakes to help prevent the wires from breaking off.

While the piezo transducer will probably come with red and black wires, the connections required are not polarised and it doesn't matter which wire is used for each 'piezo' position.

Temperature sensor

Depending on the application, the temperature sensor may need to be made into a probe – eg, suitable for immersion into aquarium water or another solution.

We used a ballpoint pen casing such as a BIC for this and removed the ballpoint pen and ink refill and the end cap. Wire up the sensor to single cored shielded cable with the centre conductor going to the + terminal of the LM335Z (the centre pin) and the shield to the – side (See Figs. 1 & 3).

Make sure that the shield and centre conductor cannot short together or to the other pin (use short lengths of heatshrink if necessary).

Pass the shielded cable through the narrow end of the tube and position the sensor at the wider end. Use aquarium-rated silicone sealant to make physical contact between the sensor and the inside of the casing and to seal off the end. Make sure the sealant does not make contact with the bare leads on the sensor or the wiring as it may corrode them, due to its acid cure properties.

The wire exit is also sealed, again using the aquarium-rated sealant, along with the small air hole in the pen tube if there is one. The opposite end of the cable is soldered to a 3.5mm mono jack plug, which mates with the 3.5mm socket on the temperature alarm. The centre conductor connects to the tip of the plug.

Testing and setting up

Apply power and plug in the sensor. Measure the voltage between TP GND and TPS. Write down the reading and read the air temperature with as accurate a thermometer as you can lay your hands on. Assuming an ambient temperature of 25°C, the voltage should be somewhere around 2.98V. Typical sensors will be 10mV/K but some may vary from this.

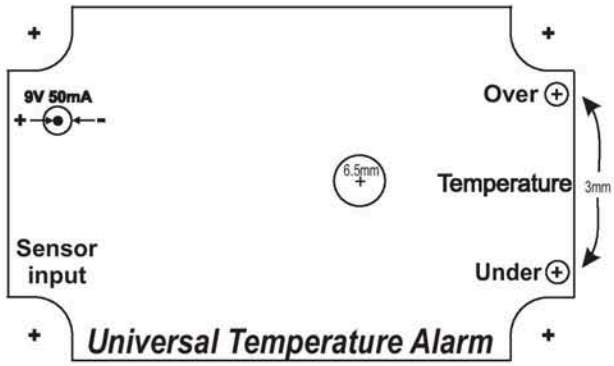
From the temperature reading and voltage, you can work out the voltage per Kelvin from your particular sensor. So if you have a reading of 2.95V and the temperature reading on a thermometer is 22°C, this is 295K (you add 273). So 2.95V/295K gives 10mV/K.

A different sensor may provide a 3.0V reading for a thermometer reading of 24°C – (297K) gives 3.0V/297K or 10.1mV/K.

To set the upper and lower thresholds for the Temperature Alarm, just calculate the voltage for the tempera-

Same-size drilling template for the lid of a UB5 Jiffy Box. The "fishy" version, with holes marked, can be downloaded from siliconchip.com.au

Full kits will be available shortly from all Jaycar Electronics stores – Cat KC5533 @ $39.95



ture required. Table 2 shows how it is done, assuming a 10mV/K sensor. The calculation is done by converting the required °C temperature to Kelvin by adding 273 and then multiplying this Kelvin value by the mV/K value of your sensor.

So for example if you want an upper threshold of 26°C and a lower threshold of 24°C (typical for aquarium use, for example), the voltage from the sensor for these two temperatures is calculated: the two temperatures are converted to K; 26 + 273 and 24 + 273. These become 299K and 297K. So for a 10.1mV/K sensor the upper threshold is 10.1mV x 299 = 3.019V and the lower threshold is 10.1mV x 297 = 2.99V.

Setting up the Universal Temperature Alarm is done by firstly setting the upper threshold by adjusting VR1 and monitoring the voltage at TP1 to get the reading required for the upper threshold.

Then the lower threshold is adjusted by adjusting VR2 and monitoring TP2 for the lower threshold voltage.

JP1 and JP2 are included so you can select whether you want the upper, lower or both thresholds to sound the alarm. JP1 is inserted for the upper threshold alarm and JP2 for the lower threshold alarm.

Both jumpers inserted will trigger an alarm when either the upper or lower thresholds is exceeded.

Boxing it

The Alarm is installed inside a UB5 case. Holes are required to be drilled in the side for the power input (CON1) and the sensor connector (CON2). A template is available that's included with the front panel artwork. This can be downloaded from the Silicon Chip website (www.siliconchip.com.au).

Two versions are available: a simple version suitable for general purpose use, or the "fishy" version shown on our prototype.

The method of producing and attaching your label are left up to you but we suggest paper printed labels should be laminated or otherwise enclosed for protection and longevity. Finally, fit the lid to the case using the four screws supplied with the case. SC

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Brownout Protector for Induction Motors

By JIM ROWE

Brownouts occur when the mains voltage drops to a very low level, say below 100VAC and this causes incandescent lamps to be very dim or "brown". But as well as making your lights go dim, brownouts can cause induction motors to burn out because they cannot start properly.

YEARS AGO, BROWNOUTS were quite rare and generally confined to rural districts where the power lines had very long runs. A falling tree or an electrocuted possum might cause the mains voltage to drop to a low level and lights would go dim.

This has always been a hazard for the induction motors used in pumps and refrigerators.

Nowadays though, because the electricity grid is running much closer to total capacity, brownouts can be experienced much more commonly in the cities and suburbs.

Our own offices in the Sydney suburb of Brookvale have had brownouts on a number of occasions in the last few years. Each time one has occurred, we have made sure that the air conditioner, fridges, compressors and other machinery in the building were turned off until full AC mains supply was restored.

Had we not done so, all the motors in that equipment were liable to burnout.

So how many motors in your home are at risk right now if a brownout was to occur?

The list can be quite long: fridge, freezer, washing machine, dishwasher, air conditioner, pool pump, spa pump and perhaps one or two garage door openers; typical of many homes. All this equipment could attempt to turn on during a brownout and the motor(s) would probably burn out.

Maybe your insurance policy covers motor burnouts but you would need to read the fine print. The insurance company might also look askance at your claim if there was more than one motor burnout or if the appliances were more than a few years old.

The problem is that if induction motors try to start when the mains voltage is very low, they will never come up to correct speed and they will consequently draw very heavy currents. Unless they are turned off within a minute or so, they are very

likely to burn out their windings.

The risk applies to all induction motors in appliances which can switch on at any time, as in refrigerators, airconditioners, water/sewer pumps on rural properties and the other appliances listed above.

But you can take out your own "insurance" against this possibility by building our Brownout Protector.

It monitors the AC mains voltage and disconnects power to the appliance when the voltage drops below a preset level, only reconnecting it when the voltage returns to its normal level.

This project is a considerably revised version of the Brownout Protector published in our December 2008 issue.

That project worked well but the original kit and PCB is no longer available and we've had requests asking if we could come up with a revised version which would be physically smaller and lower in cost.

Specifications

A low cost brownout protector for single phase 230VAC induction motors with power ratings up to 2300W.

Features include an adjustable voltage threshold, switch-on delay and indication of both normal power and brownout conditions.

Maximum control power: 2300W

Switch-on delay: 5 seconds (approx)

Standby power consumption: <5W with relay on

Brownout threshold voltage: typically set to 200V

This would make it cheaper to build multiple units, to protect each vulnerable appliance in a home.

Hence this new Brownout Protector is smaller and will cost less to build, while still offering all of the features of the 2008 design.

These include the ability to adjust the low-voltage switching threshold (typically set to 200VAC), plus a heavy duty relay to perform the switching.

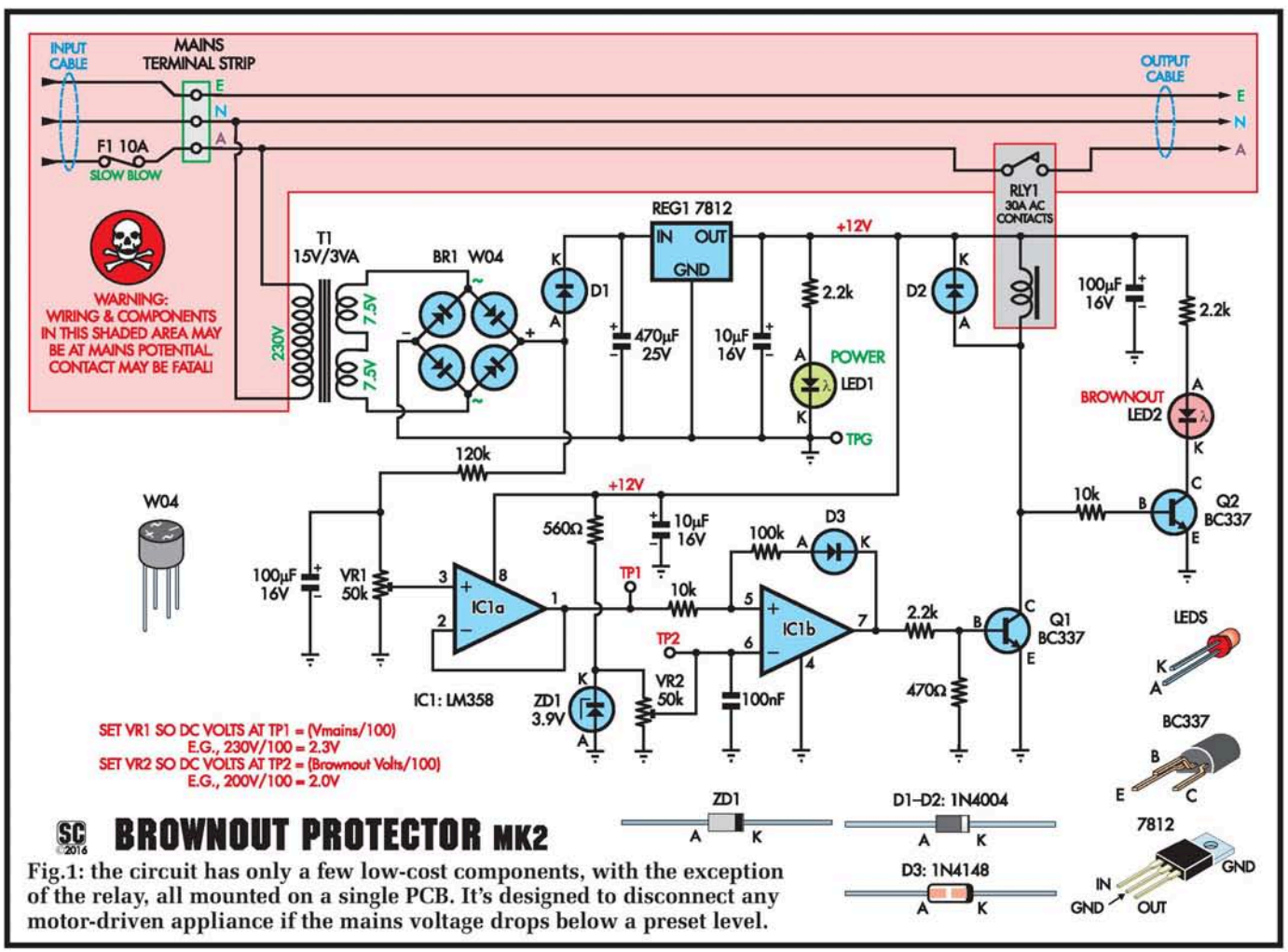
The relay contacts have a continuous current capacity of 30A and an inrush current capacity of 65A, ensuring that it is more than capable of switching loads of up to 2300W (= 10A at 230V).

The circuit also has a time delay of approximately five seconds after the mains voltage drops below the threshold level, before the relay switches off power to the motor.

There is also built-in hysteresis, to make sure that the mains voltage has to rise above the threshold level by about 10V before the motor power is switched back on again. This ensures that the relay is prevented from "chattering", or rapidly switching on and off if the mains voltage lingers at the threshold level.

Circuit operation

The full circuit is shown in Fig.1. It uses only a small number of low-cost



SC 2016 **BROWNOUT PROTECTOR MK2**

Fig.1: the circuit has only a few low-cost components, with the exception of the relay, all mounted on a single PCB. It's designed to disconnect any motor-driven appliance if the mains voltage drops below a preset level.

components. These include dual op amp IC1, two BC337 transistors (Q1 and Q2), a 12V regulator (REG1) and the heavy-duty relay RLY1.

Power for the circuit is derived from the mains via a small 15VAC 3VA stepdown transformer, T1. This drives bridge rectifier BR1, with diode D1 used to couple the bridge output to the 470µF filter capacitor. The resulting nominal 19V DC is then fed to the input of regulator REG1. The output of REG1 then provides the 12V DC to power IC1, the 12V relay and both LED1 and LED2.

To detect a brownout condition, the circuit needs to monitor the AC voltage from the transformer secondary winding.

But we don't do this directly; instead we monitor the rectified DC waveform at the output of BR1 and the anode of D1. This is filtered using the 120kΩ resistor and the 100µF capacitor across trimpot VR1.

The resulting DC voltage across VR1 is about 3.6V. Note that this voltage does not necessarily track the 19V or so that appears across the 470µF main filter capacitor.

This is because the 470µF capacitor charges up to the peak value of the rectified 15V waveform, whereas the 120kΩ resistor, trimpot VR1 and 100µF capacitor form an averaging filter to give a lower voltage (Vp x 0.636 x 50kΩ ÷ 170kΩ = ~3.6V).

But why go to all this trouble rather than just monitoring the DC voltage across the 470µF main filter capacitor? After all, if the mains voltage varies, the voltage across the 470µF capacitor will vary in proportion, won't it?

The reason for using this averaging filter method is twofold.

First, the actual AC waveform of the mains supply is usually "flat topped" due to the loading of gas discharge lighting (eg, fluorescents) and the capacitor-input switchmode power supplies used in most of today's computers and other electronic equipment.

Using the peak of the waveform to represent the actual mains voltage is not sufficiently accurate because the degree of "flat topping" varies during the day, depending on whether it is a peak or off-peak period.

Second, when the relay switches on and off, it causes a considerable variation in the voltage across the 470µF main filter capacitor.

For example, we measured a voltage of 16.1V across this capacitor when the relay was energised (on), but around 18.2V when the relay was off – a variation of more than 10%.

In contrast, the measured averaged voltage across VR1 was 3.7V with the relay on and 3.8V with the relay off, a variation of just over 2.5%.

This is important because in the worst case, the brownout detector needs to respond to an actual variation in the mains voltage from 216VAC (the normal minimum mains voltage) to 200VAC (the switching threshold).

This is a variation of only 7.5% and we don't want the circuit being confused by variations in the supply waveform.

Trimpot VR1 is included so that the sample voltage fed to IC1a (which is connected as a unity gain buffer) can be set to exactly 1/100th of the mains AC voltage value.

To give an example, if the mains voltage is 230VAC, VR1 is adjusted so the DC voltage at the output of IC1a (ie, at TP1) is exactly 2.3V. This is part of the calibration procedure and just why we do this should become clear shortly.

The voltage at TP1 is fed to the non-inverting input (pin 5) of IC1b, which is connected as a comparator.

A nominal 3.9V reference voltage is provided by zener diode ZD1, which is fed via a 560Ω resistor from the +12V supply.

Trimpot VR2, connected across VR2

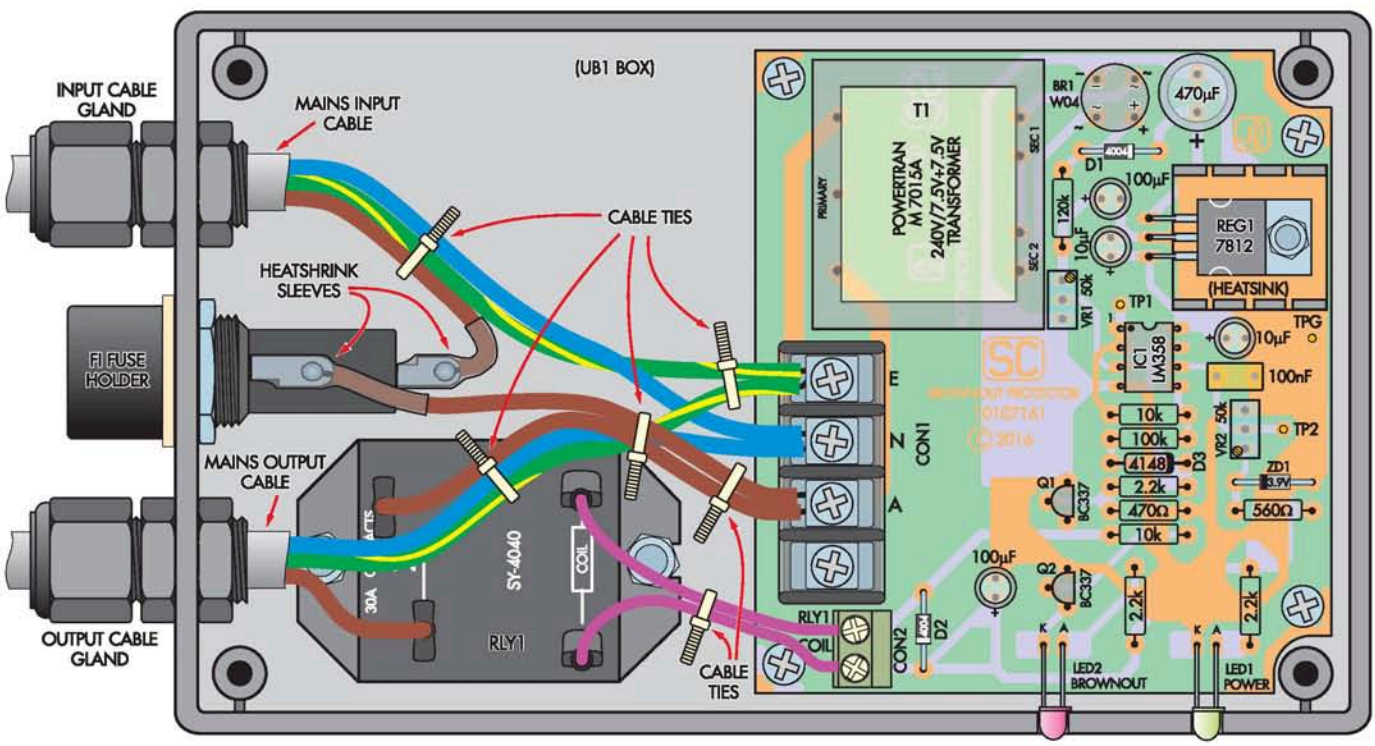


Fig.2: same size diagram showing the component overlay on the PCB, along with the mounting of the board and various hardware in the UB1 jiffy box. Note the extensive use of cable ties to hold mains wiring securely in place.

sets the switching threshold for IC1b, with its wiper connected to IC2b's inverting input (pin 6) and to TP2.

This allows the voltage at pin 6 to be set to about 2.0V, representing a brownout threshold detection point of 200VAC.

So with a normal mains voltage, the voltage at pin 5 of IC1b will be 2.3V (230VAC÷100). This voltage is higher than the 2.0V at pin 6 and as a result the output of IC1b will be high (close to +12V). This switches on transistor Q1, which powers relay RLY1.

The relay contacts then supply power to the appliance connected to the Brownout Protector's output cable.

When IC1b's output is high, diode D3 will be reverse biased and so the 100kΩ resistor connecting back to pin 5 has no effect on circuit operation.

However, should the mains voltage drop just below 200VAC, the voltage at pin 5 of IC1b will go below the 2.0V threshold set at pin 6 and so output pin 7 will go low. This will switch off transistor Q1 and the relay, disconnecting power from the appliance connected to the output cable.

Diode D2 quenches the back-EMF from the relay coil when its magnetic field collapses, protecting Q1 from damage.

Simultaneously, transistor Q2 switches on to light the brownout indicator LED2 – connected to the +12V supply via a 2.2kΩ resistor.

Hysteresis

When IC2b's output is low, diode D3 conducts and pulls pin 5 even lower than 2.0V due to the voltage divider action of the 100kΩ and 10kΩ resistors.

For example, if the voltage at TP1 is at slightly less than +2.0V, the output of IC1b will be very close to 0V. The anode of D3 will be at about +0.6V and so the divider action caused by the 10kΩ resistor connecting to +2.0V and the 100kΩ resistor connected to +0.6V will give a voltage at pin 5 of ((2.0-0.6V) x 100÷110) + 0.6V, or +1.87V. This is a drop in voltage of 130mV.

So instead of pin 5 now being at +2.0V, the action of the 100kΩ resistor, diode D3 and the 10kΩ resistor reduces the voltage by about 130mV, to +1.87V.

Before IC1b's output can go high again, the mains voltage would have to rise by the extra amount to make up this 130mV difference. This requires an increase in mains voltage of 13VAC, to around 213VAC.

In practice, because the average voltage at TP1 is higher when the relay is off compared to when it is on, the extra voltage required from the mains for the relay to switch back on again is around 10VAC.

This voltage difference effect is called "hysteresis", and is included to prevent the relay from rapidly switching on and off at the brownout threshold.

Provided that the mains voltage remains below the brownout threshold, the relay will remain off. In fact the relay remains off at any voltage below the threshold level, including voltages down to 0VAC (ie, a true blackout).

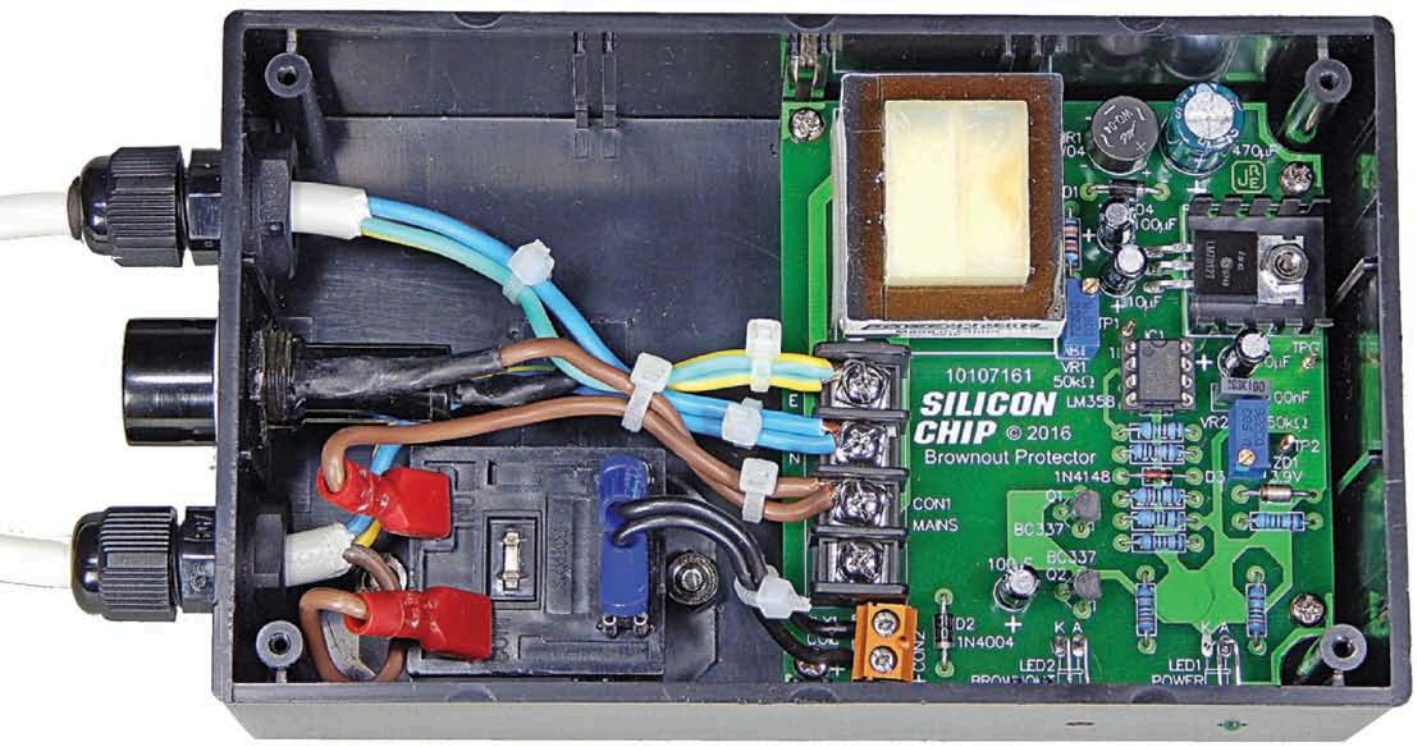
A power-on delay is included so that the relay only switches on about five seconds after power is applied.

This delay is due to the values of the 120kΩ and 100µF filter components that monitor the average voltage from rectifier bridge BR1.

These are sufficiently large so that it takes time for the 100µF capacitor to charge up to above the voltage provided at TP2.

This delay is also important to allow for the inevitable momentary drop in mains voltage caused by high surge currents every time an induction motor starts up.

Normally, these high currents only last a second or two, depending upon the appliance – and we want to be sure that they do not cause the Brownout



Here's a photo of showing the same things as the drawing at left. All exposed mains wiring (eg, to relay, fuse, etc) is insulated with either appropriate crimp connector shrouds or, in the case of the fuseholder, heatshrink tubing.

Protector to erroneously switch off the power.

Construction

The Brownout Protector is housed in a standard low cost UB1 jiffy box, measuring 158 x 95 x 53mm. All of the parts except for the mains fuseholder and mains switching relay RLY1 are mounted on a small PCB, coded 10107161 and measuring 85 x 76mm. This mounts inside the right-hand half of the box, using four 15mm long M3 tapped Nylon spacers and eight M3 x 6mm long screws.

Because this is a mains device, it's essential to use Nylon spacers and relatively short screws to maintain insulation integrity between the inside of the box and the outside world.

Relay RLY1 mounts in the left-hand half of the box, using two M4 x 10mm long Nylon screws, flat washers, lockwashers and M4 hex nuts.

Two cable entry glands, used to secure the mains input and output cables, mount in the end of the box, with a 3AG safety fuseholder between them.

The Active (brown) wire from the mains input cable solders directly to one of the fuseholder terminals while the other fuseholder terminal is connected to the Protector's PCB via a short (50mm) length of mains (brown) cable, cut from the input cable.

Both soldered joints are covered with with heatshrink sleeves for safety.

All connections between the input and output cables and the Protector's PCB are made via a four-way barrier terminal strip – although only three of the terminals are actually used.

The mains active connections to the contacts of RLY1 are made using 6.5mm insulated crimp connectors, which slide down over the relay contact lugs.

The connections to the coil of the relay (RLY1) are made via two short leads terminated with 4.8mm insulated crimp connectors at the relay ends, and connecting to a small two-way terminal strip (CON2) at their PCB ends.

All of these off-board wires are secured together using cable ties, as shown in both the overlay/wiring diagram of Fig.2 and the photograph alongside.

Also shown in this diagram and photo are the two indicator LEDs, which are mounted near the front edge of the PCB with their leads bent by 90° so that the LEDs become visible via two 3mm holes drilled in the front of the box.

This overall assembly setup should all be fairly clear from the internal photos along with the overlay/wiring diagram.

Building it

Begin construction by fitting all of the components to the PCB in the usual order: first the fixed resistors, followed by the non-polarised capacitor and then the polarised electrolytic capacitors – making sure the latter are fitted with the correct orientation.

After this mount the diodes (again watching their polarity) and bridge BR1, followed by transistors Q1 and Q2 and then IC1.

Then fit regulator REG1, which mounts horizontally on a small U-shaped heatsink with its three leads bent down by 90° at a distance of 7mm from the body of the device so they pass down through the matching holes in the PCB. A 10mm long M3 screw and nut are used to clamp the tab of REG1 to the heatsink and also both of them to the PCB.

Next solder the two trimpots to the PCB, orientating them as shown in Fig.2. Then fit the four-way barrier terminal strip CON1, making sure all four of its connection pins are soldered securely to the pads under the PCB so the terminal strip is held firmly in place.

Install the smaller two-way terminal block CON2 for the relay coil connections, along with the pair of wires connecting this and the relay coil. While this connection is low voltage, the wire is in an area with lots of mains connections, so its insulation should be rated at 250V.

This is followed by the largest component of all: power transformer T1. Take care again to solder all seven of its connection pins to the pads under the PCB, so the transformer will be held firmly in place.

The final items to be fitted to the PCB are the two LEDs, which should each have both their leads bent down by 90° at a distance of 9mm away from the body. These are then soldered to the appropriate pads on the PCB with the axis of the LEDs and their leads as close as possible to 7.5mm above the PCB. This is to allow them to protrude slightly through the matching holes in the box after final assembly.

When you are bending the LED leads before soldering them to the PCB, you need to make sure that they're being bent the correct way – so the longer anode lead of each LED will be able to pass through the right-most hole in the PCB.

Your PCB assembly can be placed aside while you prepare the box for final assembly of the project as a whole.

There are only 11 holes to be drilled in the main part of the box. You'll find full details of all of the holes in the drilling diagram, which you can download from www.siliconchip.com.au

We suggest that you drill all the holes first with a 3mm drill, then enlarge holes D with a 3.5mm drill and holes E with a 4mm drill. You can also enlarge holes B and hole C at the same time, and then use an 8mm drill to enlarge them further. Then holes B and C can be enlarged to their final sizes of 12.5mm and 15mm using either a "stepped" drill bit or a tapered reamer.

When all holes have been drilled, remove any swarf on both sides of each hole using a countersink bit or a small rat-tail file.

Although there are no holes to be drilled in the box lid, you might like to attach to it a small dress panel like the one in our photos. The artwork for this is shown in Fig.3, or it too can be downloaded and printed in colour from www.siliconchip.com.au

We printed this out on plain paper, hot laminated it and then cut it out to size using sharp scissors. Then it

An extension cord is cut to form the mains input and out leads.

was attached to the box lid using thin double-sided adhesive tape (spray adhesive also works well!).

Final assembly

Final assembly should not give you any problems if you do the steps in the following order.

First, mount relay RLY1 in the bottom of the box on the left, with its larger staggered mains connection lugs towards the left as shown in Fig.2. Secure it in position using two M4 x 10mm Nylon machine screws with flat washers, lockwashers and nuts above each of the relay's mounting flanges. Make sure you tighten both screws up firmly using a screwdriver and nut driver or spanner.

Now fit the four M3 tapped 15mm long Nylon spacers to the bottom of the box on the right, using M3 x 6mm screws passing up through holes A from underneath. Do not tighten these screws up too firmly at this stage though, because the spacers may need to be nudged slightly during the next step, which is to lower the PCB assembly down into that side of the box until it's sitting on the spacers.

Make sure you don't damage the two LEDs or bend their leads too much when you're lowering the board into place. It should now be possible to line up the LED bodies with the holes in the front of the box and just poke them through so they can be seen from outside the box.

You should now be able to fit the four remaining M3 x 6mm screws near the corners of the PCB, to mesh with the holes in the tops of the four spacers, thus fastening the PCB assembly in position. Complete the tightening of the lower screws as well, to ensure that the PCB assembly is firmly locked in place.

Now fit the two cable glands into holes B in the left-hand end of the box, fastening them in position using a pair of small spanners – one to hold the hex nut moulded into the body of the gland, and the other to turn the actual mounting nut on the inside.

Now you can fit the safety 3AG fuseholder into the 15mm diameter hole in the centre of the left-hand end of the box, tightening up its mounting nut with a small spanner while holding the fuseholder's outer barrel with your hand so it doesn't rotate far enough to make its connection lugs too difficult to access for soldering the active wires.

Next take the 3m long 230V/10A extension cord and cut it in two equal lengths. The half with the 3-pin plug on the end will be used for the Protector's input cable, while the other half (with the 3-pin socket) will be used for the output cable.

Cut off a length of around 150mm from the cut end of the input cable, which will be used to provide the two short lengths of brown (active) mains lead for making the connections between the fuseholder, barrier terminal strip and one of the relay contact lugs.

Now remove about 90-100mm of the outer sheath from the cut ends of both the input and output cables, freeing the three internal wires. Remove 10-15mm of insulation from these six wires.

Then remove the outer clamping 'nuts' from the two cable glands, and slip each nut onto one of the cut ends of the cables (outer end first).

After this you need to push the end of each cable into and through its corresponding cable gland, until about 10mm of the cable's outer sheath is protruding through the gland into the interior of the box.

Then bring the outer clamping nut for that gland back up the cable and thread it back onto the gland's outer thread, tightening it up to make sure the cable is being clamped securely in

The two LEDs are mounted at right-angles to the PCB so they just poke through appropriate holes drilled in the side of the case. For a detailed case drilling diagram, refer to www.siliconchip.com.au

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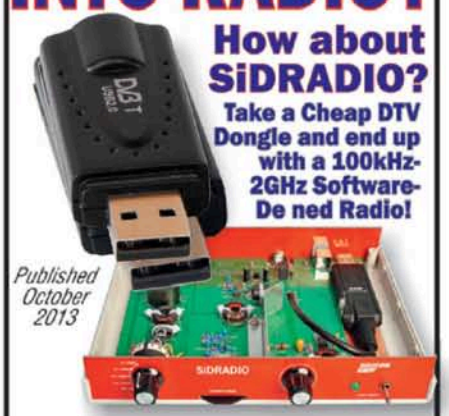

Published October 2013

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Parts List

1 UB1 size jiffy box, 158 x 95 x 53mm
1 Double-sided PCB, 85 x 76mm, code 10107161
1 240V to 15V power transformer, 3VA, PCB mounting *(Powertran M7015A or similar)*
1 SPST relay with 12V coil and 30A/230V contacts *(Jaycar SY-4040 or equivalent)*
2 M4 x 10mm machine screws, nuts, flat washers and lockwashers
2 6.5mm spade connectors (for relay contacts)
2 4.8mm spade connectors (for relay coil)
1 Panel mounting 3AG fuseholder, 'very safe' type *(Jaycar SZ-2025 or equivalent)*
1 10A slow-blow 3AG fuse cartridge
2 Panel mounting cable glands for 3-6.5mm diameter cable *(Jaycar HP-0720 or similar)*
2 20mm lengths of 5mm heatshrink sleeving
6 Nylon cable ties, 100-150mm long
1 3m long 230V 10A extension cord *(cut in half to use for the Protector's input and output cables)*
4 15mm M3 tapped Nylon spacers
2 10mm M3 Nylon machine screws
8 6mm M3 machine screws
1 10mm M3 machine screw
3 M3 hex nut
1 U-shaped TO-220 heatsink, 19 x 19 x 9.5mm
1 4-way PCB mounting barrier terminal strip (Altronics P-2103 or equivalent)
1 2-way PCB mounting terminal block
3 1mm PCB terminal pins

Semiconductors

1 LM358 dual op amp, DIL8 (IC1)
1 7812 12V regulator (REG1)
2 BC337 NPN transistors (Q1, Q2)
1 3mm green LED (LED1)
1 3mm red LED (LED2)
1 W04 400V/1A bridge rectifier (BR1)
2 1N4004 1A diodes (D1, D2)
1 1N4148 signal diode (D3)
1 3.9V 1W zener diode (ZD1)

Capacitors

1 470µF 25V RB electrolytic
2 100µF 16V RB electrolytic
2 10µF 16V RB electrolytic
1 100nF MKT polyester

Resistors (1/4W, 1%)

1 120kΩ 1 100kΩ 2 10kΩ
3 2.2kΩ 1 560Ω 1 470Ω
2 50kΩ multi-turn vertical trimpots

that position and can't be pulled out.

This should all be repeated for the second (output) cable.

(If you want to prevent any possibility of the gland becoming loose and not providing proper cord anchorage, you can put a drop of super glue on the thread before tightening the nut.

But don't do this until you have made sure the project is fully working because it will make the nut impossible to remove!)

Next cut off about 40mm from the input cable's brown (Active) lead and strip off about 6mm of the insulation from the end of the remainder.

This will allow it to be soldered to the rear lug of the fuseholder – but before doing so, slip a short length (say 20mm) of 5mm diameter heatshrink sleeving over the lead and slide it up to the end near the cable's outer sheath. This is to avoid it shrinking prematurely.

Solder the end of the lead to the fuseholder lug, and after the solder joint has cooled down you should be able to slide the heatshrink sleeve back up the lead until it has covered both the joint and the metal lug. Then apply heat to the sleeve using the side of your soldering iron's tip (without touching it), so that it shrinks securely in position.

A similar job needs to be done on the brown (Active) lead of the output cable, only in this case it needs to be shortened by about 50mm, again with 6mm of the insulation stripped from the remainder, and then fitted with a 6.5mm insulated crimp connector to attach to one of the relay contact lugs.

The blue (Neutral) and green/yellow (Earth) are all left at their full length of 90-100mm but with about 12mm of insulation stripped from the end of each one.

The bared wires of the two Earth leads should then be twisted tightly together. The same needs to be done with the two Neutral leads.

They should then be fitted under the clamping plates of the matching terminals on the barrier strip, after the screws have been loosened. The Earth leads need to be fitted under the rearmost 'E' terminal screw, of course, while the Neutral leads go under the next 'N' screw.

Make sure you retighten each screw firmly after the wires are in place under the screw's clamping plate.

The next step is to remove the brown (Active) lead from the 150mm length of cable you cut from the 'input' cable earlier, and cut it into two 75mm lengths. One of these will be used to make the lead connecting from the side lug of the fuseholder to the active (A) terminal of the barrier strip, while the other will be used to make the lead connecting the same barrier strip terminal to the second contact lug of RLY1.

It's probably easiest to strip 6mm of insulation from one end of each lead, and 12mm from their other ends.

The shorter bared end of one lead will then be soldered to the side lug of the fuseholder, with another 20mm length of 5mm heatshrink sleeving slipped over the joint and lug once they have cooled down, then heated once more to shrink over them securely.

The bared end of the other short brown lead should then be fitted with a 6.5mm insulated crimp connector, to attach to the second contact lug of the relay.

Finally the wires on the 12mm bared ends of these two short active leads should be twisted tightly together and then clamped under the 'A' terminal screw of the barrier strip.

Finally, cut two 60mm lengths of insulated hookup wire, strip off about 6mm of insulation from both ends, and then fit one end of each wire with a 4.8mm insulated crimp connector to mate with the coil lugs of RLY1.

The other end of each wire should

Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	120kΩ	brown red yellow brown	brown red black orange brown
❑	1	100kΩ	brown black yellow brown	brown black black orange brown
❑	2	10kΩ	brown black orange brown	brown black black red brown
❑	3	2.2kΩ	red red red brown	red red black brown brown
❑	1	560Ω	green blue brown brown	green blue black black brown
❑	1	470Ω	yellow violet brown brown	yellow violet black black brown

Same-size "cover all" front panel artwork for the Brownout Protector, to fit a standard UB1 jiffy box. If you prefer, you can cut out the inner (gray) section and centre that on the lid. (This panel, along with a hole drilling diagram, can also be downloaded from www.siliconchip.com.au).

be clamped under one of the two screw terminals on the smaller terminal strip (CON2) at the left front of the PCB.

All of your off-board wiring will then be complete, and all that remains is to fit about six cable ties to the leads to prevent them from 'wandering' if one of the solder joints, screw terminals or crimp connectors should come adrift.

The suggested positions of these cable ties are shown in Fig.2.

Unscrew the front insert of the fuseholder and fit it with a 10A slow-blow 3AG fuse cartridge and then screw it all back together again.

Don't attach the lid to the box yet, because the two trimpots on the PCB still need to be adjusted to set up the Protector correctly.

Setup procedure

There's not a great deal involved in setting up the Protector correctly, but you are going to need at least one good digital multimeter (DMM) – and ideally two of them.

As the setting up must be done with the lid left off the box, be very careful while you're doing it. Be especially careful not to touch either the active (A) or neutral (N) screw terminals on the barrier strip – this could be fatal!

All other "bitey bits" should of course be shrouded or covered in heatshrink.

Plug the Protector's input cable into a convenient power outlet and switch on the power. You should see LED1 glowing to show that the circuit is powered up. Don't worry too much about whether LED2 also glows as well, or if you hear the relay click on instead.

But if you want to make sure that the power supply circuit is working correctly, you can use your DMM (set to measure say 20V DC) and check the voltage between test point TPG and pin 8 of IC1.

If you get a reading of +12V, this will confirm that all is well.

Next, set your DMM to measure at least 250VAC and very carefully touch the tips of its test leads to the screws of the 'A' and 'N' terminals on the main barrier strip, making sure you don't touch these yourself in the process, or touch them together.

Note the reading and then remove the test leads.

Now set the DMM to measure DC volts again, and clip its input leads to test points TPG and TP1, to measure the voltage between them. You're aiming to get a reading here of 1/100th the AC mains voltage you just measured, ie, 2.30V DC if your measured mains voltage was 230VAC.

The odds are that the reading you get will be some distance away from this correct figure, either higher or lower.

Not to worry though; all you need to do is adjust trimpot VR1 (just to the right of transformer T1) until the voltage reading rises or falls to the correct figure or as close as possible to it.

Since the mains voltage can vary somewhat at different times of the day, the above measurements of the mains voltage and the DC voltage at TP1 should ideally be done at the same time – using two different DMMs.

However, if you only have a single DMM just try to make one measurement soon after the other and perhaps recheck them both again after you believe you've found the right setting for VR1.

Just make sure you remember to reset the DMM correctly to change from high voltage AC to low voltage DC and vice-versa!

The remaining setup adjustment is even simpler. All that's needed is to clip the DMM test leads to test points TP2 and TPG and adjust trimpot VR2 until you get a reading of 2.0V.

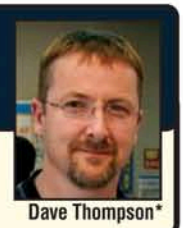
(If you want the brownout voltage threshold to be other than 200VAC, set this to 1/100th the voltage you want).

Once this second setup adjustment has been made, you can turn off the power, remove the DMM test leads and then screw the lid onto the Protector's box to complete its assembly.

Your Brownout Protector should now be ready to begin work, protecting the induction motor from damage in the event of one of those nasty power brownouts. SC

SERVICEMAN'S LOG

No magic hammers with smart TVs



Dave Thompson*

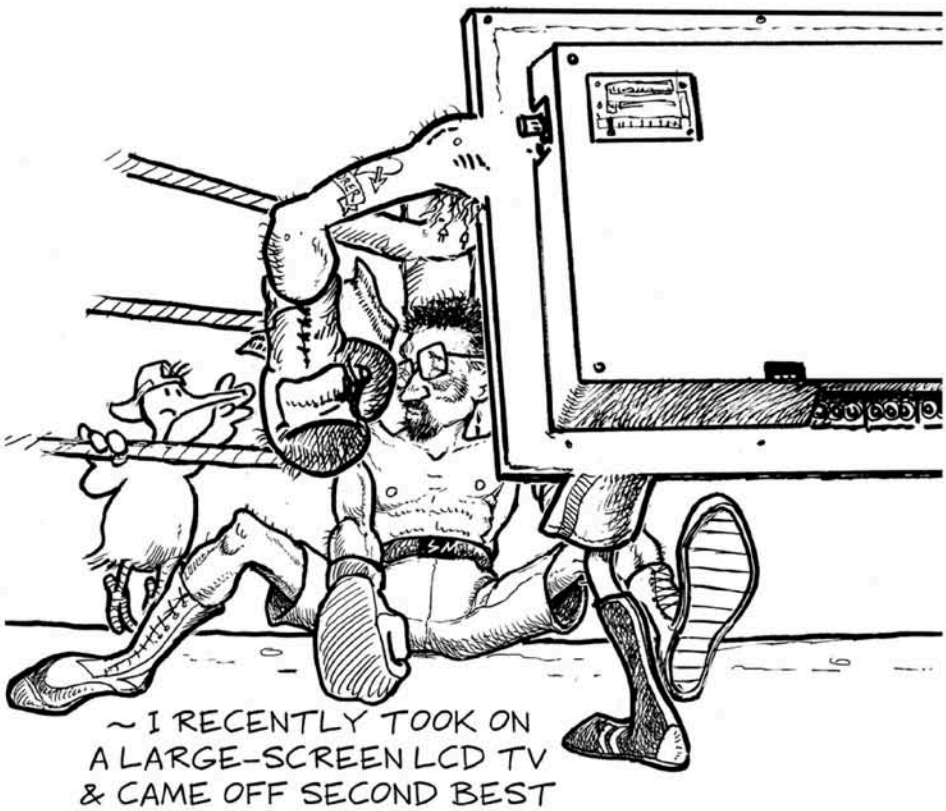
You don't always win in the servicing game. I recently took on a large-screen (140cm) LCD TV set but despite my best efforts, I ended up coming off second best.

I'm not usually into repairing TV sets, preferring instead to let professional TV servicemen handle those specialised jobs. However, when a client recently asked me if I "did TVs", I answered "yes, I do", surprising myself even as the words came out.

Not wanting to obviously back-pedal, I then asked him what was wrong with it. My thinking was that he might describe a symptom that would give me the chance to bail out gracefully by claiming that, unfortunately, I couldn't repair "that" type of problem.

His response was that it worked fine at switch-on but that the screen then went dark a minute or so later. To me, that sounded like it should be quite straightforward to repair, my thoughts being that it was probably just a dud connection or something along those lines. He then told me that the TV was only about a week old, so why hadn't he simply taken it back for a warranty claim? It turned out that he'd lost the receipt and apparently the retailer was being extremely pedantic about not taking the set back without it.

While I can understand this stance on one hand, surely they could have dug around and found the relevant sales details, especially as the set had only been purchased from them the week before. However, they wouldn't budge and so the customer was at a bit of a loss as to what to do.



Items Covered This Month

- My first smart TV repair
- CPR on an Engel fridge
- Sobering up a groggy pH meter
- Penny's air-conditioner

Feeling his pain, I said I'd look at it for him but that I couldn't promise anything. It was a neat little exit strategy to fall back on if necessary. If the job proved too difficult, I could simply point out that I'm really a computer technician rather than a bona-fide TV repair guy.

With the customer's expectations dealt with, it was just a matter of him hauling the TV in from his vehicle. For some reason, I was expecting a relatively small set but he turned the corner cradling a monster 55-inch (140cm) flat-screen TV. It took just one look to convince me that the tiny cabin I currently use as a temporary workshop was not going to be the best place to troubleshoot this device!

Despite its size, it was as light as a feather and in fact a child could've lifted this TV! Nevertheless, I took one end and helped him carry it down the driveway to my garage workshop, which is a lot larger and better set up for electronic repairs than the cabin.

Signs of life

When we got there, I plugged the set in, switched it on and instantly saw a bright blue splash screen. After a few seconds, the TV circuitry switched in but the screen was all hash due to the lack of an antenna. However, rather than connect an antenna, I plugged in a flash drive I had hanging about the workshop and used the remote to select the USB input, whereupon the media menu came into view. I then chose a random AVI file from the flash drive and away it went.

To be completely honest, it wasn't the best picture I'd seen on a TV but

this set was a "cheapie" and given its relatively low sale price (about half the cost of a similar "big-name" branded set), it was perfectly acceptable. We watched the video for about two minutes and then the screen suddenly flickered and quickly faded to black, although the sound was unaffected and continued along happily in the background. "That's what it does to me too!", the customer exclaimed.

I promised again that I would do my best and the customer left to allow me to carry on with more pressing work. I subsequently returned to the TV a few days later and this time, before plugging it in, I whipped the back off.

This initially involved removing the relatively heavy base and stand assembly (the two weighing as much as the rest of the set put together) before removing half a dozen large panel screws situated around the perimeter of the case. It was then just a matter of cracking the clips holding it together in between the screw points, after which the back panel lifted away easily to reveal, well . . . not very much at all.

My first smart TV

This was the first big smart TV I'd disassembled and to be honest, I expected a little more inside than I discovered. Pretty much 80% was fresh air, there being just two moderately-sized circuit boards and one smaller board screwed to pillar mounts on the rear of the screen panel. The power supply was up near the middle left side of the panel, while down at the centre bottom sat the smaller T-Con (timing and control) board. On the mid-right side sat the main audio/video/tuner board.

Of these, the biggest was the power supply board and it measured just 120 x 180mm. As a result, all the boards looked rather lost in the vast, empty expanse behind the screen area.

Being a "more common" type of serviceman, I reached for my hammer to begin troubleshooting the TV! Yes, my hammer and while you may well picture a large engineers' ball-pein hammer wreaking its havoc among the chips and transistors, you'd be wrong. This particular hammer is a small, hard plastic type and is an ideal tool for gently tapping on boards and even individual components to induce any loose connections or bad solder joints to reveal themselves.

I plugged the set in and leant it against my workbench, portrait style, with the screen facing a set of plastic drawers sitting under the bench. The faces of these drawers acted as a mirror, one of the vital aids real TV service people have in their workshops but which I don't happen to have. Admittedly, it wasn't exactly a perfect TV repair set-up but it would suffice; I could easily make out the reflected screen images on the drawers.

As soon as it was plugged in, the TV again displayed the blue splash screen, then the file menu for the USB input. As before, I chose a random movie to play and sure enough, after a minute or so, the screen went black. I then switched it off using the remote (ie, to standby rather than "'right off"), then immediately restarted it and found that the screen stayed black.

I turned it off again and decided to wait for a few minutes before switching it on again, amusing myself in the meantime by taping a row of microswitch controls safely out of the way of the power supply board. These usually mounted into the back panel but once that had been removed, had been dangling just above the power supply board via a flexible connecting strap.

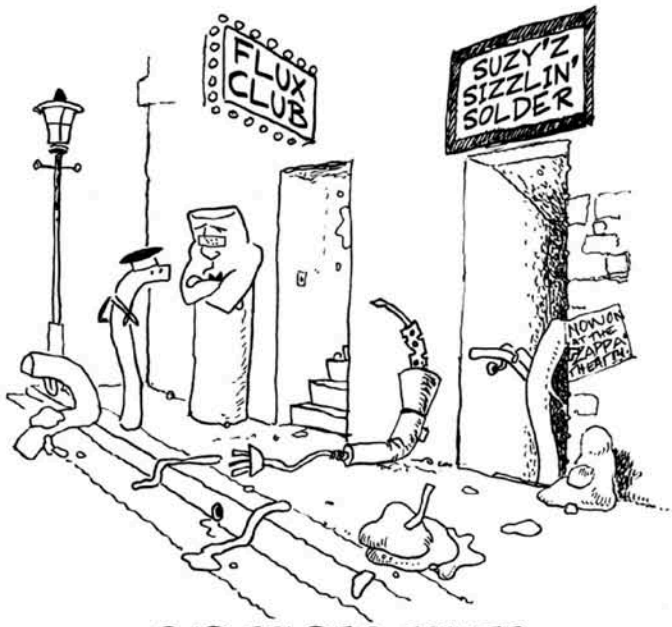
I also checked every flying lead connection (there weren't actually that many) between the boards and various satellite components like speakers, external sockets and controls. All seemed to be well-connected, using the same industry-standard connecting plugs and sockets that I'd seen in plenty of other devices. I paid particular attention to all the power supply connections, including a line of 2-pin connectors that fed the LED backlights. Everything seemed in good order; I could see nothing that would account for the screen "dying".

A red herring

When I started the TV again after the pause, the blue splash screen came up again and then the menu as before. This time though, I didn't select an input and instead began tapping away on the power supply board, hoping to induce the fade-out sooner so that I could isolate the cause of the problem. This approach seemed to pay off, because when I tapped on one of the small transformers near the centre of the board, the screen went dark.

So was I onto something or was this merely a coincidence?

I waited the prerequisite few minutes before repeating the exercise and this time, no amount of tapping would induce the problem. I tried it again with a movie playing, tapping in all directions and then once again after switching



BAD SOLDER JOINTS REVEAL THEMSELVES

off and waiting. I even tried physically manipulating the transformer casing (it felt very solid to me) but I couldn't replicate the fault, which meant that it was probably a coincidence.

No magic hammer

When the screen did eventually fade out, I powered it up again after a suitable interval and this time hit the other boards with my plastic hammer. However, nothing stood out and the screen again faded away in its own good time. As I proceeded through the testing process, I took note of how long it took the screen to fade out, in case there was a repeatable time-span. There wasn't; it was seemingly random. Sometimes it went for just 20 seconds and sometimes for as long as three minutes. Once, after tapping the main board, it ran for almost five minutes and here was naive me thinking my magic hammer had done the business.

In the end, the bottom line was that I couldn't find any mechanical fault that caused the screen to die. This meant that magic hammers are for the movies and I'd have to look further afield and utilise my troubleshooting skills to discover the cause of the problem.

Before proceeding further though, I stripped all the connectors from the power supply board and removed it from its mounts on the back of the panel. I then took it to my other workshop and proceeded to examine it under my microscope, looking for fractured or incompletely soldered joints, etc. However, it looked to be very well made and a quick Google search for the part numbers revealed that this same power supply graces many smart TVs, including models made by Blaupunkt and Seiki.

A replacement power supply on eBay was only about $US30 but I wasn't convinced that that was where the problem lay. In fact, more Googling revealed information posted on TV repair forums that indicated that the most likely cause of this issue was the T-Con board. This is the smallest board in the set and it connected directly to the screen via two large, flexible cables.

I removed this board and gave it the microscope treatment but once again, nothing obvious was apparent. A web search turned up several used-but-guaranteed replacements for only $40, so I hit the buy button and got one on the way. This component is also used in Blaupunkt TVs and as that brand has a good reputation for quality, I wouldn't consider it second-tier hardware.

The new board arrived in just five days (not bad from the USA) and I installed it in minutes. This time, when I fired up the TV, it ran for 20 minutes but that was hardly cause for celebration. At the end of that time, the screen flickered to black. It would then recover seemingly at random but would only run without glitching for a couple of minutes at the very most.

A faulty board?

That was a real blow because it meant that I was dealing with something else, unless I'd had the misfortune of getting a faulty secondhand T-Con board. However, at this stage it wasn't worth sending it all the way back to try another one, even though the vendor kindly offered to swap it for me. He was surprised at the outcome and had been reasonably confident that it would have fixed the issue.

I went back to the power supply board and started taking voltage measurements at various points when the screen went dark, comparing these with the voltages obtained when the screen was working. I found that the backlight voltage remained relatively stable, although it did drop slightly when the backlighting went dark.

By now, any talent I have for repairing TVs had long since been exhausted and so, clutching at straws, I ordered another power supply. During this process, I'd kept the customer up-to-date with what I was doing and he'd agreed to cover the costs of any parts I needed to get it going. Because the TV was a cheap model, he figured that he had a little leeway as far as spending money on it went and thus he could afford to take a gamble and buy these less expensive parts for it.

Once again, the power supply arrived quickly and I soon had it fitted into the set. And once again it worked fine at first but the screen soon went black and that was that!

Love lost

I was seriously starting to fall out of love with this thing by now. Not only was it taking up room in my workshop but it was also soaking up a lot of my time and it wasn't the simple fix

Servicing Stories Wanted

Do you have any good servicing stories that you would like to share in The Serviceman column in SILICON CHIP? If so, why not send those stories in to us? In doesn't matter what the story is about as long as it's in some way related to the electronics or electrical industries, to computers or even to car electronics.

We pay for all contributions published but please note that your material must be original. Send your contribution by email to: editor@siliconchip.com.au

Please be sure to include your full name and address details.

I thought it would be. The input board was the only part left that I could easily replace and although I tracked down a replacement, it was new and a lot more expensive than the other parts. What's more, from what I'd read in the online forums, it was unlikely that this board was the problem and this was borne out by even more research I did on the issue.

Apparently, this board couldn't "do" anything that would cause the backlights to go dark. It could fill the screen with artefacts and other related faults but not make it go black, according to the "experts" on the forums and the various parts guys I talked to when buying the other replacement boards. I also had a gut instinct that I'd be wasting my time and my customer's money by swapping that board out with a new one.

And then I discovered some interesting information on one of the forums. I stumbled on this while searching for scraps of information about the various boards used in this TV and learned that while many 55-inch sets utilised the exact same power supply, some of the cheaper sets shipped with bad LED arrays. When they went dark, repair technicians assumed that the power supply was the problem but it was actually a screen issue; or, more accurately, a problem with the LED backlights.

This made sense; if the various circuit boards were first rate, one place left for the manufacturers of these second-tier products to cut costs would be the screen. From my research, I knew that the boards were good enough for brand-name sets, which made it even more likely that the problem lay in the one part I couldn't easily replace – the screen!

I was now going to have to break this news to the owner who was not going to be a happy camper.

The fact is, we'd have to buy a whole new screen assembly to get this TV going and while there may be one available somewhere out there, I haven't looked for one as my time and the customer's expenses so far have edged this repair into the "not economically feasible" bracket. The best I could do was recommend that he place a wanted ad on some of the local sales sites on the web, in the hope that someone has a dead version of the same model TV but which has a good screen.

Provided the dead set was cheap enough, we could swap the good bits out of his set into that one. In addition, he could then advertise any leftover good boards for sale while he was at it.

You win some and you lose some; that's the servicing business!

CPR on an Engel fridge

Compact fridges capable of running off mains or battery power can really come in handy. B. C. of Dungog, NSW recently resurrected one such unit that had been rescued from the recyclers . . .

Deciding that it might make a good project, a friend recently bought an Engel 240VAC/12V DC (Model MT45F-G4) refrigerator at the recyclers. The leaves and mud were washed away and we carefully dismantled the unit. Eventually, an enclosed metal box was removed and after the four connecting leads were unplugged, it was eased out from under the external condenser.

This box, which contained all the electronics, had been beside the compressor (which is basically a solenoid pump). With a grin, he handed it to me and said "what's inside is your department".

At the bottom end of the box was an input connector for the 240VAC, along

ZENER, WARRIOR DIODE (ZD103), FIGHTS EVIL OVER-VOLTAGES

with a 12V DC input which is protected by a blade type 10A DC fuse. Removing a number of screws and pop rivets subsequently revealed two rectangular PCBs and some flood residue inside.

Everything was then thoroughly washed in warm water, after which the two PCBs and the input connector block were immersed in methylated spirits for a few hours. All these were then allowed to dry in the sun for a number of days.

Switchmode supply

Closer examination of the two PCBs then revealed that one was a 240VAC SMPS (switchmode power supply), while the other was the compressor driver unit. My main concern at this stage was to try to ensure that the switchmode transformer (T1) was completely free of moisture. I also removed the silicone insulator (which encased Q101) to ensure it was dry inside. The compressor driver PCB had all open-type toroidal coils fitted and it had fully dried out.

At this stage, we decided to test-run the refrigeration unit from 12V DC,

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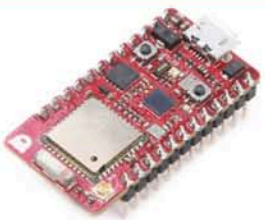

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Sobering up a groggy pH meter

A little wine is supposedly good for the heart but not when it gets into the heart of a pH meter. P. E. of Heathcote, Victoria was able to cure the groggy instrument of its hangover . . .

I was recently given a "simple" job to repair a Hanna Instruments HI 8314 pH meter, which was used to measure the pH of wine. I was told that it originally cost several hundred dollars and that it had stopped working. Well, that narrows it down!

The instrument looks like a fancy multimeter and is used in a similar way. My first thoughts were that copper and wine don't mix and while it may have been an expensive instrument, it wasn't very well sealed from liquids. The buttons on the front were similar to a modern dishwasher and while they were well sealed, the calibration adjustment screws at the bottom would allow liquids (including wine) to enter inside the case.

It was a simple matter to open it up; just undo four screws and pry the two halves of the case apart. It wasn't clipped together like a typical TV remote though. Instead, I had to pry it because it was stuck with dry, gooey wine.

Sure enough, the main PCB had been awash with wine and this wine was now dry and had done its deed on the copper tracks and on the two 100kΩ multi-turn trimpots used to calibrate the instrument. Two copper tracks had gone completely but I was able to see where they'd been due to the green solder mask.

Removing the trimpots was like pulling teeth as the PCB is double-sided with plated-through holes and the pots were also stuck fast with wine goo. I ended up destroying another track on the board getting them out but it was easy to replace this and the two missing tracks with fine insulated copper wire.

I then soaked the PCB in methylated spirits for about 10 minutes and then very gently scrubbed it with a small paintbrush. Eventually, the goo all came free and, fortunately, there didn't seem to be any more damage to the copper tracks. I also gave the second, smaller PCB that held the lead sockets a quick clean in metho (although it already looked clean) and tested the connections from the leads to this board. One of these connections was open circuit but was easy to fix by carefully bending the contacts using a small screwdriver and spraying on some WD40 for good measure.

Fitting new 100kΩ trimpots was child's play compared to removing the old ones. The battery lead was also replaced, after which the plastic case was given a good clean with soapy water and everything allowed to air-dry in the sun.

After reassembling it, I was greeted with an LCD screen with numbers on it so it was all looking good. I had no idea how to use it but the owner subsequently reported that it works.

I advised him to keep wine well away from it!

with power coming from a DC output socket in the back of his Landrover. The correct protected 12V DC Engel power lead had been borrowed from another member of the family but before plugging it in and running the test, a timber cover was placed on top of the fridge where the lid normally sits.

The various leads from the compressor, thermostat, temperature sensor, 24V DC cooling fan and 12V DC input connector were then all plugged into the correct compressor driver PCB terminals. A digital multimeter set on a low AC range was then connected to the compressor terminals, after which the Engel power lead was plugged into the Landrover's DC output socket. The multimeter immediately displayed close to 12VAC and a steady hum came from the compressor.

After it had been running for a few minutes, I could feel the temperature getting colder on the inside condenser. And then, with the thermostat knob on position 2, the unit cut out after about 10 minutes. It subsequently cut back in again about 10 minutes later, so all was good so far.

Now for the 240VAC SMPS. Back on the workbench, I replaced the 33µF/35V electrolytic capacitor near the M51995 IC (IC101), as its measured ESR was borderline. I then removed the T3.15AMP ceramic fuse (F101) and soldered a test lamp (240VAC/60W) in its place.

That done, a dummy load (2 x 470Ω 5W wirewound resistors in parallel) was connected to the DC output terminals. The original 240VAC input connector and lead were then plugged into the other end of the PCB and an IEC power lead plugged into the outlet of a 240VAC-to-240VAC isolation transformer.

Switching it on

The time had now come to switch it on! When I did so, the test lamp lit briefly on the input surge and the multimeter displayed +39V DC at the output. I tried adjusting the 1kΩ trimpot at the output end of the supply but this only allowed the output voltage to be varied by about ±1V.

At this stage, I decided to turn the power off and draw a mud-map of the output circuit. There were two PC123 optocouplers, one set up as an over-voltage protector via a 47V zener diode (ZD103) and the other controlled by an LM431 precision voltage reference and an 18V zener diode (ZD102). There was also a voltage divider set up on the input pin of the LM431.

I "googled" for an LM431 data sheet and browsed through the pages to find this important formula: Voltage Out = 2.5(1 + R1/R2). Using a calculator, the resistor values were plugged into this formula and I found that these gave an output voltage of close to +38V. So I had to assume that the previously measured +39V DC was close to the correct output voltage!

That established, fuse F101 was then refitted and the 240VAC SMPS with its 240V/240V mains isolation transformer connected to the Engel fridge. This meant that the +39V DC was now going to go through the compressor driver PCB! The 240VAC power was turned on and the multimeter, which was still connected across the compressor terminals, displayed about 13VAC.

Somehow on the way through the compressor driver board circuitry, this had all occurred correctly without any of that magic blue smoke escaping!

The fridge was then allowed to run for about an hour and it performed perfectly. After that, the two PCBs and the input connector block were shoehorned back into their box with all the associated covers, screws and pop rivets. It was then just a matter of refitting the box and soak-testing the unit for a number of hours.

My friend tells me that the resuscitated Engel fridge will be used as a drink fridge in his shed and for shopping trips.

As a postscript, there appears to be some conjecture about what is really inside the $8 Engel 3AG glass fuse, located inside the cigarette plug end of the 12V DC Engel power lead. I took the opportunity to find out and found a 168°C 10A thermal fuse in series with a 10A Pico fuse.

These Engel fridges can also run from +24V DC but it is not recommended to run these units on 240VAC from the cheaper square-wave type inverters or from the unregulated 12V DC outlets on generators.

Finally, always check for the correct polarity if you are making up DC extension leads or doing other lead modifications. There are many tales of woe on this subject on the grey nomad online forums!

Penny's air-conditioner

A split-system air-conditioner that's only seven years old shouldn't have to be replaced if it breaks down. D. P. of Faulconbridge, NSW recently did a friend a favour and got one such unit going again . . .

Recently, my wife and I were discussing the evils of the throwaway society with a friend. In particular, we were lamenting the fact that consumers are often forced to replace faulty appliances because of the difficulty and high cost of even getting a fault diagnosed, let alone repaired.

Who knows what otherwise potential gems with minor faults are now languishing in the nation's landfills, or worse still, have been shipped off to third-world countries where they are dismantled for scrap in dangerous sweatshops? Gone are the days when your dead toaster could be taken to your local friendly electrical shop, where the element would be replaced, on the spot, for a few dollars.

It was during this conversation that Penny mentioned the case of her air-conditioner. It was a split-system and had simply stopped working one day. Their children were in the room when it failed and reported that they had heard a loud "pop" from the indoor unit.

A short time later, our friends asked an electrician who happened to be at their house doing other work if he would look at the air conditioner. He took one look at it and his reply was short and to the point: "Nope . . . too old!".

They subsequently found that it was impossible to get anyone to even come and look at the air-conditioner! In each case, the advice was either that the job was too small or that the unit was too old to even consider repairing and should be replaced (it was about seven years old – plainly a dinosaur!).

So our friends were left with the prospect of replacing the whole system at considerable cost, despite the possibility that it may have had only a minor fault. As well, this was one of two identical NEC units that had been installed in the house at the same time and both had done about the same amount of service. The other unit was still functioning normally, so the catastrophic failure of a major component in the faulty unit seemed unlikely. Understandably, they hesitated to make a decision and so the dead air-conditioner languished where it was for quite some time.

When I heard this, I volunteered to have a look at their air-conditioner, to see whether or not it was fixable. I didn't promise anything but from what the children had reported, it sounded suspiciously like something electronic which meant that the repair could be straightforward.

I knew that these indoor units contain an electronics module that controls the fans and the compressor and that this module usually includes a microprocessor, various sensors, some relays and other electronic-type bits and pieces.

There is also typically a switchmode power supply with its highly-stressed electrolytics, as well as various other capacitors and relays carrying serious current in there. In short, there are plenty of things that might go "pop"!

When I arrived at the scene, the first thing I noted was that the air-conditioner wouldn't even try to start. In fact, there was no sign of life at all. I checked the circuit breaker on the power board and it was on, so I turned it off before starting work on the unit.

The component side of the bottom PCB in the NEC air-conditioner looked pristine but the underside was a different story! The black rectangular component at top right is the compressor relay, while the grey cylindrical part next to it is the T2 fuse.

Dismantling the indoor unit to get at the electronics module was easy enough. The outer cover was secured with three screws along the lower edge and after undoing these, the cover then had to be detached from snap-on mouldings along the top edge. I managed to do it without breaking anything but it would be great if more manufacturers would include markings, such as arrows, to show us where the snap-on mouldings are.

Having removed the cover, I then turned the circuit breaker back on so that I could check that power was getting to the air-conditioner. This proved to be the case so whatever was wrong was definitely in the unit itself. I then turned the circuit breaker back off so that I could take a closer look at what was going on.

Several layers

The electronics module was in a plastic box which contained several layers, the top layer carrying only mains terminals. The next layer consisted of a PCB which carried a microcontroller and numerous surface-mount components, while the bottom layer consisted of a second PCB, this time carrying through-hole components.

This second PCB looked like a switchmode power supply and carried several electrolytic capacitors, several AC-rated capacitors and various relays – in short, all the usual suspects!

I was expecting, or more precisely, hoping, to see something obvious like

This view shows the underside of the switchmode supply after it had been cleaned up. The burnt-out circuit board track with the relay pin in the middle is circled in red.

an exploded electrolytic capacitor but as I delved deeper into the innards, my hopes were rapidly fading. Everything looked pristine but when I removed the bottom PCB and turned it over, it was a completely different story. The top of the board was completely clean but about a third of the underside was covered with thick black soot.

It was impossible to determine the source of the soot at this stage and all the parts on the top of the board looked perfect. Perhaps something had once been underneath the board which was there no more?

Missing solder pad

It all became clearer once I had cleaned up the underside of the board, however. There was a relay marked "RY – COMP" (compressor relay) on the board. And where one pin of this relay had once been soldered to a PCB pad, there was now just a hole. The pad was missing!

The pin was still there though, apparently undamaged, but was now surrounded by empty space. There was no sign of solder, this apparently having been completely vaporised along with several millimetres of copper surrounding the pin.

This track had once connected the relay to the compressor, so it carried the full compressor load. As a result, I bridged the gap with copper wire and plenty of solder, making sure that the solder had wetted everything properly so that I had a good, low-resistance connection between the relay and the compressor.

The question was, what had caused the failure of the original soldered joint? Was it a power surge, due possibly to a lightning strike (quite common in this area)? Or had the relay pin never been properly soldered (a "dry" joint) so that over time, a cycle of progressive heating and oxidisation had eventually produced a high resistance joint which generated enough heat to melt the solder completely? Or had the heating originated in the relay itself, due to increasing contact resistance?

The other question was, whatever the process, had the relay itself survived? There was no sign of its plastic body overheating but I reasoned that its contact resistance could be high without any damage being visible on the outside. I was not able to find any data on this particular relay but looking at the specifications for similar devices, it seemed that the typical contact resistance for this type of relay was less than 100mΩ (milliohms).

I didn't have anything that could measure such a low resistance value but my DMM has a 200mV range, so I figured that if I passed some current through the contacts, I should be able to measure the voltage across them and accurately calculate the resistance. After some thought, I decided to use a 12V DC supply with a car tail-lamp in series to limit the current through the contacts and to also use this same 12V supply to activate the relay.

This set-up gave a contact current of 1.85A, while the voltage drop across the contacts measured 9mV. Using Ohm's Law, this then gave a calculated resistance reading of just 4.9mΩ, so it looked like the relay was OK.

However, the open circuit to the compressor did not explain the general lack of signs of life. Had the control circuitry survived the trauma? It was not going to be possible to test the entire control circuitry with it removed from the air-conditioner but I could test the power supplies. If these had survived, then there was a reasonable chance that the logic circuits were OK.

There was a switchmode supply with a +12V output, which supplied the various relays. This also fed a +5V linear regulator which supplied the logic circuits. In order to check these rails, I would need to apply 230V mains to the switchmode board itself.

Fortunately, I have an isolated (floating) mains supply in my workshop, which dates from the "hot chassis" (AC/DC transformerless) radio days and still comes in handy from time to time. It consists of two 240-110VAC transformers connected back-to-back, with a lamp socket in series with the output. I can also take the output from the first transformer only to get 110VAC if required and various incandescent lamps can be plugged into the lamp socket to limit the current to the required level. A shorting plug can be plugged into the lamp socket if full current is required.

Open circuit fuse

The switchmode regulator is fed from the mains via a slow-blow 2A fuse marked "T2 250V". This fuse is a small, grey, cylindrical, vertically mounted component and looks like an inductor at first sight. Apparently these have very specific delay characteristics and are soldered in, so presumably are not expected to blow very often.

I checked the fuse and it was open circuit, so apparently it had received a fair surge and it remained to be seen whether it had effectively protected the switchmode supply. I didn't have one of these specialised fuses on hand but I figured that by bridging it out temporarily and by using a 15W lamp to limit the current, I would be able to determine whether or not the power supply was working.

I connected it all up, connected the control board to the supply and applied power. The lamp didn't glow, no smoke came out, the switchmode regulator produced a nice clean +12V rail and the linear regulator produced a steady +5V. It was all looking good, so I decided to order a new fuse and proceed to the next step – a smoke test in the air-conditioner!

Thankfully, the final smoke test went well and our friends have a cool house again. But the question remains as to what caused the original failure. I am inclined to think that it was simply due to a bad solder joint on the relay pin, because internal heating in the relay would have damaged the contacts, while a power surge would probably have tripped the circuit breaker on the power board.

But what caused the fuse to blow? The likely answer is that it was due to a current spike that was produced by arcing as the soldered connection was burning out. SC

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Holds 8 x D, 10 x C, 25 x AA, 10 x AAA and 8 x 9V batteries, includes a storage drawer for button batteries.

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Monitor the motors on your next project. The module outputs a voltage proportional to current passing through the sense pins on the module. Based on the ACS712 IC.

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- Compact board only 31mm x 13mm

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- Processor Frequency: 8MHz
- LiPo Battery charging connector and circuitry

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Compact size, high current, variable output and fan cooling make these the ideal power supply for your bench. They are protected against thermal overload and short circuit and will display a warning LED in the event of a fault condition.

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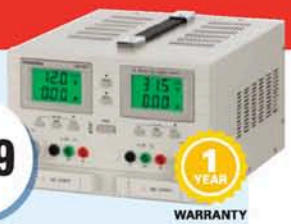
3V to 15VDC 40A Regulated Switchmode Laboratory Power Supply

MP-3090

Variable output voltage from 3 to 15VDC, or it can be fixed at 13.8VDC. The unit has overload, over temperature and over voltage protection.

- 220(W) x 110(H) x 300(L)mm.



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This automatic constant-voltage/constant-current transfer power supply is effectively two 0-32VDC 3 Amp power supplies in one. The two outputs can be operated independently, connected in parallel , or series for multiple output currents and voltages.

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25 Watt

Highly efficient and reliable power supplies that feature broad input voltage tolerances.

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MM-2012

Type 2158 single winding transformer with 200mm fly leads on primary and secondary connections.

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Features	Line interactive, economical model	Line interactive	Line interactive, LCD desktop model
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Internal SLA battery	12V/7AH x1	12V/7AH x1	12V/9AH x2
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Allows two batteries to be charged from your engine alternator at the same time.Suitable for 12VDC Marine, 4WD, caravan and solar applications.

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Charges Li-Ion, Li-Po, Ni-Cd, Ni-MH and lead acid batteries. Li-Po batteries are balance-charged so there's no risk of damage or explosion from incorrect charging. Powered by mains plug pack or a 12V battery.

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Charge various Li-ion battery packs, as well as AA, AAA or 9V Ni-MH and Ni-Cd rechargeable batteries. Includes USB port.

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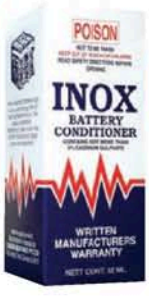
Removes or reduces sulphation which kills batteries. One bottle will do up to a N70Z size battery (4WD, boat, truck, etc.)



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This remote battery jumper terminal provides convenient access to the vehicle battery for charging or jump starting.

- Protective red & black rubber covers
- 50(W) x 130(L) x 20(H)mm

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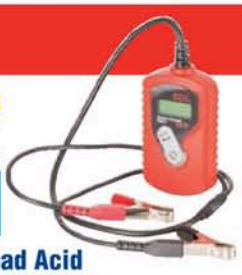

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Quickly, easily, and accurately measures the cold cranking amps capability of the vehicle starting battery.

- 6-30VDC voltage measure range
- 125(L) x 70(W) x 25(H)mm

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Super compact capacitor based jump starter, ideal for long term storage. Fast charging with high power output. Will start a warm 4.0L or cold 3.0L petrol engine or 2.0L diesel engine.

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See website for details.

20UF RU-6606
30UF RU-6608

RU-6606
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MP-3209

The pulse width modulation (PWM) used in this controller allows you to vary the output from 0 to 100% while maintaining a very high efficiency. When used on motors this ensures full torque is available at very low speed and the motor won't shudder at start-up.

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SY-4085 VALUED AT $19.95

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WITH 2 X USB AND SURGE PROTECTION
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Ideal for protecting computers from spikes and surges.

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Keep dirt and rain off a powerboard used in the garage or backyard. Holds most 4 and 6 way powerboards up to 420mm long. IP44 weatherproof rating, lockable and can be wall mounted.
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Double insulated 2 core power cable suitable for automotive and marine applications.

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See website for single-core power cables.

NERD PERKS 2x POINTS

$14.95

Pocket Wire Stripper
TH-1817

Strips anything from 2G to RG6 coax. Easy to use and small enough to take anywhere on the job.

- 120mm long.

$15.95

NERD PERKS 2x POINTS

Stainless Steel Wire Stripper, Cutter, Pliers TH-1841

High quality precision stripper/cutter. Spring-loaded with locking jaws, rubber handles for added comfort. Cuts wire up to 3.0mm. Strips wire up to 2.6mm.

TOOLS FOR TESTING POWER

$24.95

Non-contact AC Voltage Detector QP-2268

Detects AC voltages from 50 - 1000V. Can be used for detecting live mains in outlets, power boards or insulated wiring.

- Audible beeper indicator
- Flashlight function
- CAT III rated
- 2 x AAA batteries included
- 176(L) x 26(D)mm

Analogue Digital Multimeter
QM-1020

- Audible continuity
- AC/DC voltage <1000V
- AC/DC current < 250mA
- Holster included
- 150(L) x 100(W) x 35(D)mm

LIFE LIFETIME GUARANTEE

$29.95

Autoranging AC/DC Digital Clamp Meter
QM-1563

- 600V, 4000 count
- AC/DC current < 400A
- Jaw opening 30mm
- Includes test leads & temperature probe

See in store or online for our full range of clamp meters.

LIFE LIFETIME GUARANTEE

$129

$239

1 YEAR WARRANTY

Variable Laboratory Autotransfomer (Variac) MP-3080

Encased in heavy-duty steel housing, enables the AC input to a mains powered appliance to be easily varied between 0 to full line voltage (or greater). A must for testing mains performance.

- 500 VA (fused) rated power handling
- 0–260 VAC @ 50Hz output voltage
- 165(D) x 120(W) x 160(H)mm

HARNESS THE POWER OF THE SUN

80W Fixed Solar Panel Package ZM-9310

Comes with everything needed to set up the complete power system with minimum wiring. See individual components for full details and warranty information.

VALUED OVER $1026

PACKAGE INCLUDES:

12V 80W SOLAR PANEL ZM-9097 **$219**
12V 8A PWM SOLAR CHARGE CONTROLLER MP-3720 **$64.95**
BATTERY BOX HB-8500 **$109**
12V 100AH DEEP CYCLE SLA GEL BATTERY SB-1695 **$519**
12V IP67 LED STRIP LIGHT ST-3950 **$99.95**
4MM FEMALE PV CONNECTOR PS-5100 **$7.50**
4MM MALE PV CONNECTOR PP-5102 **$7.50**

$920

SAVE OVER $106

MI-5720

FROM $539

1 YEAR WARRANTY

Portable Power Pure Sine Wave Inverters WITH SOLAR REGULATORS

12VDC to 230VAC inverters with built-in PWM solar charge controller allowing you to connect a solar panel (without regulator) directly to the inverter to recharge the connected battery or battery bank.

600W WITH 20A SOLAR REGULATOR MI-5720 **$539**
1000W WITH 30A SOLAR REGULATOR MI-5722 **$699**
1500W WITH 30A SOLAR REGULATOR MI-5724 **$899**

See online or in-store for our extensive range of solar panels to suit.

SOLAR ACCESSORIES

SZ-2090

FROM $9.95

Power Distribution Posts WITH BRIDGE PLATE

Heavy duty stainless steel posts mounted on a moulded plastic base.

SINGLE M10 SZ-2090 **$9.95**
TWIN M8 SZ-2092 **$11.95**
TWIN M6 POWER SZ-2094 **$11.95**

FREE FUSE & HOLDER FOR NERD PERKS CARD HOLDERS* SZ-2016, SF-2200 **Valid with purchase of AA-0348*

SZ-2016 VALUED AT $3.50
SF-2200 VALUED AT $0.40

$29.95

12V 5A Battery Charging Regulator FOR SOLAR PANELS AA-0348

Ideal for charging 12V SLA batteries from solar panels up to 60 watts. 5 amp fuse and fuse holder recommended - not supplied.

- <3.9mA (LEDs on) own power consumption
- 72(W) x 50(D) x 43(H)mm

$24.95

High Current Bolt-Down Fuse Holder SF-1980

Designed for high current protection. Eliminates nuisance blowing during temporary, short duration overloads.

ALSO AVAILABLE:

BOLT-DOWN FUSE 125A SF-1982 **$9.95**
BOLT-DOWN FUSE 250A SF-1984 **$9.95**

FROM $149

12VDC SLA Deep-Cycle Gel Battery

Leakproof and completely sealed, ideal for solar power, 4WD, camping, etc

26AH SB-1698 **$149**
38AH SB-1699 **$239**
100AH SB-1695 **$519**

1 YEAR WARRANTY

$64.95

12V 8A Water Resistant PWM Solar Charge Controller MP-3720

Suitable for both wet-cell and sealed lead-acid batteries. Uses pulse width modulation for optimal 3-stage charging. Compatible with all types of solar arrays. Potted in epoxy resin making it water resistant and suitable for use in areas of high humidity. Features over current, over voltage, short circuit, over temperature and reverse polarity protections. 97(L)x46(W)x26(H)mm.

Visit website for full specifications.

FROM $179

Solar Charge Controllers WITH LCD DISPLAY

Protect your valuable solar installation and maximise battery service life with our photovoltaic (PV) charge controller.

12V 20A MP-3129 **$179**
12V 30A MP-3722 **$219**

SOLAR PANEL LEADS, CONNECTORS, & CABLES

FROM $4.95/m

NERD PERKS 2x POINTS

Solar PV Cable

Very tough cable, specifically for the rigours of outdoor use in solar panel installations. Dust, age and UV resistant, tinned copper conductors to minimise corrosion.

- 1000VDC
- IP65 rated
- Sold per metre

58A 4MM SQ. WH-3121 **$4.95**
76A 6MM SQ. WH-3122 **$7.95**

PS-5100

$7.50 ea

NERD PERKS 2x POINTS

Waterproof Solar Power PV Connectors

IP67 rated for maximum environmental protection.

- 1000VDC rated voltage
- 30A at 70°C, 25A at 85°C rated current

4MM FEMALE INLINE PS-5100
4MM MALE INLINE PP-5102
6MM FEMALE PANEL MOUNT PS-5104
6MM MALE PANEL MOUNT PP-5106

ANDERSON® CONNECTORS & LEADS

PT-4480

$7.95 ea

Anderson® 35A SBS Mini Connectors

Compact high-current polycarbonate connectors to meet multiple needs.

- Anderson's smallest SBS connector
- Touch-safe housing
- 30(L) x 23(W) x 10(H)mm (excluding wire)

BLACK PT-4480
RED PT-4482
GREY PT-4484

NEW

PT-4425

$9.95 ea

Anderson® 50A Power Connectors

You'll find this connector in many 4WD applications, boating, automotive and other industries. Supplied as a moulded 2 pole with contacts. 50A, 600V (AC or DC).

WITH 8 GAUGE CONTACTS PT-4425
WITH 10-12 GAUGE CONTACTS PT-4427
WITH 6 GAUGE CONTACTS PT-4420

$19.95

Solar Panel PV Plug & Socket to Anderson® Plug - 300mm

PS-5122

Anderson connectors one end (50A), PV connectors on the other end. 4mm² conductor 30 amp capacity, twin sheath high-quality cable; get the maximum output from your solar panels to your regulators.

ALSO AVAILABLE:

PV CONNECTOR TO EYE TERMINAL LEAS PS-5124 **$19.95**

NEW

PS-5110

NERD PERKS 2x POINTS

$19.95 ea

Solar Panel 'Y' Leads

Used for connecting the output of two solar panels in parallel or connecting multiple panels in an array. Waterproof and UV resistant.

2 SOCKET TO 1 PLUG PS-5110
2 PLUGS TO 1 SOCKET PS-5112

INTRODUCING 'LINKER' - A NEW RANGE OF ARDUINO® COMPATIBLE ACCESSORIES

We are excited to announce a new range of modules & accessories called 'Linker', which make it easy to enter the world of Arduino®.
Simply attach the the Linker Shield to your Arduino® compatible mains board, then connect them all together using the Linker Leads.
The Linker Shield has standard Arduino® headers, allowing you to further expand your projects.
See website for details: http://www.jaycar.com.au/ardublock

NEW

$4.95

Linker Tilt Module

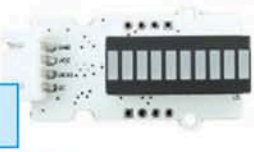
FOR ARDUINO® XC-4575

The Linker Tilt Module is the equivalent of a button, and is used as a digital input. It is wired to the SIG line, NC is not used on this kit.

- 27.9(L) × 25.4(W) ×10.6(D)mm

NEW

$9.95



Linker LED Bar

FOR ARDUINO® XC-4568

- Controls 10 LED's
- Create bar graph displays
- 44.1(W) x 24.2(H) x 11.5(D)mm

NEW

$4.95 ea

Linker Jumper Leads

FOR ARDUINO®

Connects Linker kit sensors/modules and Linker kit base shield. 2.54mm headers for easy and tidy connection. 4 pins, 2.54mm spaced.

- Sold individually

200M XC-4558
500M XC-4559
1000MM XC-4560

NEW

$24.95

Linker Base Shield

FOR ARDUINO® XC-4557

This is the base shield of Linker kit, it allows simple and tidy connection between all Linker sensors/modules and Arduino/pcDuino.

- 1 x SPI, 2 x IIC, 1 x UART connections
- 69(W) x 59(H) x 18(D)mm

NEW

$11.95

NEW

Linker 4-Digit 7-Segment Module FOR ARDUINO® XC-4569

Uses a chipset of TM1637 to drive a 12-pin 4-digit command anode 7-segment LED. The MCU only needs two GPIO lines to control it.

- I2C interface
- 46.2(W) x 24.3(H) x 14.5(D)mm

NEW

$13.95

Linker High Power LED Module

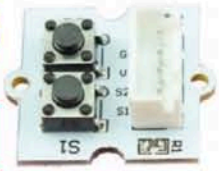
FOR ARDUINO® XC-4570

A high power LED module for the Linker kit. It has five very bright white LEDs to use as lamp or camera flash.

- SMD 3528 LEDs
- 3.0-3.4V working Voltage
- 20mA operating current
- 28.9(W) x 20(H) x 9.5(D)mm

NEW

$4.95



Linker Double Button Module

FOR ARDUINO® XC-4573

Two momentary push buttons mounted on a single board for Arduino/pcDuino via the Linker connection. Can be used as a pair of reset and switch buttons.

- 25(H) × 21(W) × 11(D)mm

NEW

$5.95

Linker Buzzer Module

FOR ARDUINO® XC-4580

Generate sound at the audible 2kHz range.

- Can also sense sound
- 25.0(L) × 25.0(W) × 10.6(D)mm

NEW

$19.95

Linker RTC Module

FOR ARDUINO® XC-4584

The clock/calendar provides seconds, minutes, hours, day, date, month, and year. Utilises a Lithium cell battery (CR1225).

- 42.1(L) × 24.2(W) × 10.6(D)mm

NEW

$39.95

Linker Serial Servo Module

FOR ARDUINO® XC-4586

A servo driver board that can drive up to 8 servos with a precision of 5us. The communication interface is TTL UART serial port, and compatible with Linker kit interface.

NEW

$6.95

Linker Temperature Module

FOR ARDUINO® XC-4576

Uses a Thermistor to detect the ambient temperature. The resistance of a thermistor will increase when the ambient temperature decreases.

- 20.0(L) × 20.0(W) ×10.6(D)mm

NEW

$9.95

Linker Path Tracking Sensor Module FOR ARDUINO® XC-4590

Infrared light is emitted and reflected back to the receiver, which is then inverted by 74LS14 and output to the output pin and the LED.

NEW

$14.95

Linker Sound Sensor

FOR ARDUINO® XC-4582

Detects the sound strength of the environment. The value of output can be adjusted by a potentiometer.

- 42.1(W) × 24.2(L) × 10.6(D)mm

NEW

$14.95

Linker Hall Sensor

FOR ARDUINO® XC-4577

Hosts an magnetic hall sensor that senses the presence of magnetic field.

- 20.0(L) × 24.2(W) × 10.6(D)mm

NEW

$6.95

Linker Rotary Potentiometer Module FOR ARDUINO® XC-4578

Produces analogue output between 0 and Vcc (5V DC with Arduino) on its D1 connector. The angular range is 300 degrees with a linear change in value.

- 10kΩ resistance value
- 25.0(L) × 25.0(W) × 18.8(D)mm

NEW

$9.95

Linker Infrared Receiver Module FOR ARDUINO® XC-4583

Used to receive infrared signals and for remote control detection.

- Can receive signals within 10 metres.
- 20.9(W) × 24.8(L) × 11.5(D)mm

NEW

$9.95

Linker Magnetic Switch Module FOR ARDUINO® XC-4581

Based on encapsulated dry reed switch of single-pole, single throw (SPST) type, having normally open ruthenium contacts. A double-ended type sensor, may be actuated with an electromagnet, a permanent magnet or a combination of both.

- 20.0(L) × 24.2(W) × 10.6(D) mm

NEW

$10.95

Linker Touch Sensor

FOR ARDUINO® XC-4572

A capacitive touch sensor to replace a push button. Low in power consumption, fast response and easy to operate. Voltage reads 0V when idle, changes to 5V when touched.

- 28(W) x 24(H) x 8(D)mm

ARDUINO® PROJECT FOR NERD PERKS CARD HOLDERS

SEE STEP-BY-STEP INSTRUCTIONS ON www.jaycar.com.au/lbc

Build Your Own Lithium Battery USB Charger

DIY

So you've just finished building your Arduino® project, and it's happily running off the USB lead hanging out of your computer. And if it something like the Arduino® compatible clock that looks at home on a desk, then everything is fine. But if it's something you want to use away from a computer like the Secret Knock Detector, or even outside where there's not even a power point (like the Breathaliser), then here's an option for you. It will also remotely charge your smart devices!

Completed project.

VALUED OVER $33

BUNDLE DEAL INCLUDES:

ARDUINO COMPATIBLE LITHIUM BATTERY USB CHARGER MODULE XC-4502 **$4.95**
14500 RECHARGEABLE LI-ION BATTERY 800MAH 3.7V NIPPLE SB-2300 **$9.95**
ARDUINO COMPATIBLE 5V DC TO DC CONVERTER MODULE XC-4512 **$4.95**
15KOHM 1/2 WATT 1% METAL FILM RESISTORS - PK.8 RR-0600 **$0.55**
4AA SWITCHED BATTERY ENCLOSURE PH-9282 **$2.95**
USB A TO USB MICRO B LEAD 1.8M WC-7724 **$9.95**

NERD PERKS CLUB
BUY ALL FOR $24.95
SAVE 25%

WC-7724

PH-9282

RR-0600

XC-4512

SB-2300

XC-4502

ARDUINO® COMPATIBLE PROJECT ESSENTIALS

$4.95

5V DC to DC Converter Module

XC-4512

Capable of providing a stable 5V, from a single Li-Po or two Alkaline cells. Input is via two solder pads, output is via a female USB socket.

- 34(L) x 16(W) x 8(H)mm

NEW

$29.95

Red LED Dot Matrix Display

ARDUINO® COMPATIBLE XC-4621

Controller circuitry is built onboard so the display only needs six digital pins to control all 512 LEDs.

- 10mm LED pitch
- Can be daisy-chained for larger displays
- Use a 5V 3A Power Supply (MP-3480) for full brightness
- 320(W) x 160(H) x 30(D)mm

ALSO AVAILABLE:

WHITE LED DOT MATRIX DISPLAY XC-4622 **$39.95**

SAVE 20% ON THESE FREETRONICS ACCESSORIES

freetronics

$27.95

SAVE $7

4-Channel PoE Midspan Injector

XC-4254 **WAS $34.95**

Power up to four EtherMega's (XC-4256) or EtherTen's (XC-4216) with DC from a low cost plugpack across your home or office network cables. It isolates and powers the correct wires automatically.

$31.95

SAVE $8

H-Bridge Motor Driver Shield

XC-4264 **WAS $39.95**

Directly drive DC motors using your Arduino® compatible board and this shield.

- Drives up to 2A per motor channel
- All outputs are diode and back-EMF protected
- 60(W) x 54(H) x 12(D)mm

MORE POWER OPTIONS FOR YOUR ARDUINO® PROJECTS

Portable Arduino® Compatible Power Supply WITH 9V BATTERY

A quick and easy portable power supply that doesn't need any soldering can be made from a screw terminal DC plug and a 9V battery snap. Just make sure the red wire goes to the + terminal!

NERD PERKS CLUB
BUY ALL FOR $18.50
SAVE 10%

VALUED OVER $20

BUNDLE DEAL INCLUDES:

2.1MM DC PLUG WITH SCREW TERMINAL PA-3711 **$4.95**
9V BATTERY SNAP PH-9232 **$0.70**
9V ALKALINE ECLIPSE BATTERY 6 PACK SB-2417 **$14.95**

PH-9232

PA-3711

SB-2417

NEW

$19.95

DC-DC Boost Module

WITH DISPLAY XC-4609

Used to provide higher voltages for your project, such as running 5V Arduino® projects from Lithium batteries.

- Output from 5V-56V
- Input range 3.5V-35V
- Maximum 2A input current without heatsinking

EARN A POINT FOR EVERY DOLLAR SPENT AT ANY JAYCAR COMPANY STORE* & BE REWARDED WITH A $25 JAYCOINS GIFT CARD ONCE YOU REACH 500 POINTS!

**Conditions apply. See website for T&Cs*

REGISTER ONLINE TODAY BY VISITING:
www.jaycar.com.au/nerdperks

CLEARANCE

1.2V Ni-MH D Size Rechargeable Battery Nipple 5000mAh

SB-9010 **WAS $12.95**

- Charge rate slow: 500mA x 15 hours
- Charge rate standard: 1500mA x 5 hours
- Charge rate fast: 5000mA x 1.5 hours

NOW $9.95
SAVE $3

6V 500mA Sealed Lead Acid Battery Charger MB-3516 WAS $24.95

240V plug in power pack for charging lead acid batteries. Automatically switch to trickle charge automatically when the battery is charged.

- Energy Authority approved
- Include spade clips

NOW $17.95
SAVE $7

4-WAY USB Mains Adaptor

MP-3454 **WAS $29.95**

- Input voltage : 100 - 240VAC
- Output: 5VDC, Group A: 2.4A or 2x1.2A, Group B: 2.1A or 2x1.0A
- 85(H) x 55(W) x 44(D)

NOW $24.95
SAVE $5

Dual Battery Volt/Current Monitor

MS-6176 **WAS $179**

Enables you to monitor your start battery voltage and total battery activity of your auxiliary battery, as well as the current (amps) flow on your house battery - both charging and discharging. Unit features buzzer alert system if house battery falls below 11.5V (or over 15.5V).

- Front panel dimensions: 72(W) x 65(H)mm
- Mounting hole: 2 or 52mm
- Shunt dimensions: 135(L) x 30(W) x 25(H)mm

NOW $139
SAVE $40

Elite Household Power Monitor

MS-6200 **WAS $119**

LCD display gives you clear live power consumption, live running costs, stores your usage by day/week/month, and calculates your average daily, weekly and monthly power and running costs. Kit includes weatherproof transmitter with CT sensor.

NOW $89
SAVE $30

24V 400A Jump Starter & Power Bank

MB-3752 **WAS $399**

Equipped with high-capacity Lithium polymer (Li-Po) battery. Powerbank function to charge USB devices up to 2.1A. Front LED light and a foldable side light. Overload, over-heating, short circuit and reverse polarity protection. Supplied with battery clips, car and home charger and interchange DC plugs. Will start a large cruise boat!

NOW $299
SAVE $100

12/24V 25A Switchmode Battery Charger

MB-3608 **WAS $469**

Nine step fully automatic 25 amp high current charger with maintenance charging of all types of SLA batteries as well as lead-calcium batteries from 50 - 500Ah, either 12V or 24V. Safe to leave connected for months at a time.

- Short circuit and reverse polarity protection & anti-spark protection
- Standby, fault, mode selection and charging LED indicators
- IP44 Rated
- 260(L) x 135(W) x 70(H)mm

NOW $389
SAVE $80

12VDC to 230VAC Pure Sine Wave Inverters

These inverters include advanced control logic which provides protection from -overload, high temperature, over/under input voltage, and output short circuit, as well as a three stage output overload alarm and shutdown, and a power saving mode option. Includes a standard 230VAC mains outlet as well as a USB port for powering and charging USB devices.

180 WATT 12VDC TO 230VAC
186(L) x 117(W) x 57(H)mm, 850g MI-5700
WAS $249 NOW $219 SAVE $30

360 WATT 12VDC TO 230VAC
230(L) x 118(W) x 57(H)mm, 1.05kg MI-5702
WAS $319 NOW $299 SAVE $20

MI-5700

FROM $219
SAVE UP TO $30

TERMS AND CONDITIONS: REWARDS / NERD PERKS CARD HOLDERS FREE GIFT, % SAVING DEALS, DOUBLE POINTS & MEMBERS OFFERS requires **ACTIVE** Jaycar Rewards / Nerd Perks Card membership at time of purchase. Refer to website for Rewards/ Nerd Perks Card T&Cs. **ON PAGE 1:** Nerd Perk Card holders receive free Banana Piggyback Test Leads (WT-5326) valued $29.95 & free Heavy Duty Jumper Test Lead Kit (WC-6020) valued $11.95 with the purchase of MP-3840. **ON PAGE 3:** Nerd perk card holders receive double points with the purchase of SB-2468, SB-1611, SB-2300, SB-2308, SB-2315, SB-2301, SB-2313, SB-2319, SB-2305, SB-2307 & SB-2317. **ON PAGE 4:** Nerd Perk Card holders receive a free Heatsink (SY-4085) valued $19.95 with the purchase of SY-4084 or SY-4086. Double points with the purchase of PS-4106, PS-4100, PS-4105, PS-4115, PS-4120, PS-4117, H-3057, WH-3079, WH-3087, WH-3063, TH-1817 & TH-1841. **ON PAGE 5:** Special price $920 for 80W Fixed Solar Panel Package (ZM-9310) applies to ZM-9097, MP-3720, HB-8500, SB-1695, ST-3950, PS-5100 & PP-5102. Nerd Perk Card holders receive free Fuse (SZ-2016) valued $3.50 & Fuse Holder (SF-2200) valued $0.40 with the purchase of 12 V 5A Battery Charging Regulator for Solar Panels (AA0348). Double points with the purchase of WH-3121, WH-3122, PS-5100, PP-5102, PS-5104, PP-5106, PS-5110 & PS-5112. **ON PAGE 7:** Special price for XC-4254 & XC-4264. Nerd Perk Card holders will receive XC-4502, SB-2300, XC-4512, RR-0600, PH-9282 & WC-7724 for $24.95. Nerd Perk Card holders will receive PA-3711, PH-9232 & SB-2417 for $18.50. **ON PAGE 8:** Special price for SB-9010, MB-3516, MP-3454, MS-6176, MS-6200, MB-3752, MB-3608, MI-5700 & MI-5702. **DOUBLE POINTS ACCRUED DURING THE PROMOTION PERIOD** will be allocated to the Nerd Perks card after the end of the month.

Australian Capital Territory

Belconnen	Ph (02) 6253 5700
Fyshwick	Ph (02) 6239 1801
Tuggeranong	Ph (02) 6293 3270

New South Wales

Albury	Ph (02) 6021 6788
Alexandria	Ph (02) 9699 4699
Bankstown	Ph (02) 9709 2822
Blacktown	Ph (02) 9672 8400
Bondi Junction	Ph (02) 9369 3899
Brookvale	Ph (02) 9905 4130
Campbelltown	Ph (02) 4625 0775
Castle Hill	Ph (02) 9634 4470
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Wagga Wagga	Ph (02) 6931 9333
Warners Bay	Ph (02) 4954 8100
Warwick Farm	Ph (02) 9821 3100
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Queensland

Aspley	Ph (07) 3863 0099
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Strathpine	Ph (07) 3889 6910
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Woolloongabba	Ph (07) 3393 0777

Victoria

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Frankston	Ph (03) 9781 4100
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Kew East	Ph (03) 9859 6188
Melbourne City	Ph (03) 9663 2030
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Springvale	Ph (03) 9547 1022
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Werribee	Ph (03) 9741 8951

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Elizabeth	Ph (08) 8255 6999
Gepps Cross	Ph (08) 8262 3200
Modbury	Ph (08) 8265 7611
Reynella	Ph (08) 8387 3847

Western Australia

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Arrival dates of new products in this flyer were confirmed at the time of print but delays sometimes occur. Please ring your local store to check stock details. Savings off Original RRP. ***Prices and special offers are valid from 24 June - 23 July, 2016.***

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Occasionally there are discontinued items advertised on a special / lower price in this promotional flyer that has limited to nil stock in certain stores, including Jaycar Authorised Stockist. These stores may not have stock of these items and can not order or transfer stock.

PRODUCT SHOWCASE

Philips releases the world's first Quantum Dot monitor in Australia

Cleverly adding a layer of nano-sized semiconducting particles to the LED backlight (aka Quantum Dots), this new monitor from Philips takes advantage of the desirable photoluminescence properties of the quantum dots, dramatically increasing the colour gamut of the monitor at very little additional cost.

Whereas previously it would cost around $1,000 for a 27" monitor that could reproduce the full Adobe colour spectrum, the Philips does it for under $400.

A boon for amateur photographers or in fact anyone just needing a better colour monitor on a budget, the Philips 27" 276E6ADSW/276E6ADSS Quantum Dot IPS monitor is available now.

Contact:
Philips Monitors

Tel: 1300 906 047
Web: www.philipsmonitors.com.au

ElectroneX Showcases New Innovations and Solutions

ElectroneX – The Electronics Design & Assembly Expo returns to Sydney on 14-15 September at Australian Techology Park, which is located a few minutes south of the city centre.

Australia's largest event for electronics design and manufacturing alternates annually between Melbourne and Sydney and is the major focal point for the electronics industry in Australia. The expo is open to engineers and professionals to help them keep up to date with the latest electronics technology developments and innovations for systems integration and production electronics.

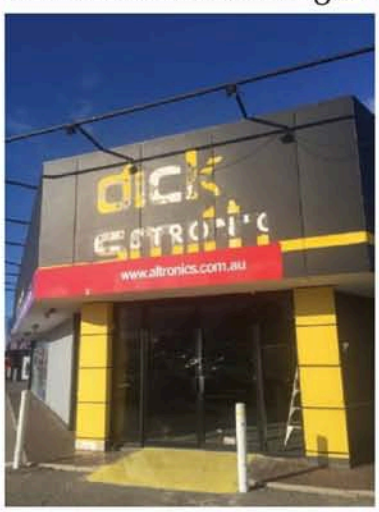
Design, electronic & electrical engineers, OEM, scientific, IT and communications professionals and service technicians are invited to attend the event where they will find the latest technology driving future product & system developments. This specialised trade event continues to enjoy strong support and is the pre-eminent electronics technology showcase and conference in Australasia.

Electronex comprises a major trade show with over 90 companies showcasing and demonstrating the latest new product releases for industry, scientific and commercial applications.

The SMCBA – Electronics Design & Manufacture Conference is being held in conjunction with the exhibition and over 1000 trade visitors are expected to attend the two-day event. Following the success of the new free seminar series that was introduced in Melbourne last year, a seminar theatre will also be established on the show floor where visitors can attend a series of short presentations on topical industry subjects. Details will be announced on the show web site closer to the event.

Contact:
Australian Exhibitions & Events
PO Box 80, Turramurra NSW 2074
Tel: (03) 9676 2133 **Fax:** 9676 2533
email: ngray@auexhibitions.com.au

Dick Smith Cannington, WA flagship store re-emerges as . . . Altronics Cannington!



For 17 years, the Dick Smith Electronics Cannington (WA) store was one of the flagship stores of the empire, until it closed its doors for the last time on April 16 as part of that company's demise.

Ironically, the DSE store's biggest competitor was the close-by Altronics store (in fact, it was right next door!) . . . and now it has risen, Phoenix-like, as the Altronics Cannington store.

Brian Sorenson, Altronics General Manager, said that the corner location of the old DSE store had superb exposure to Albany Highway so when the premises became available, it was a "no brainer" to move their Cannington store to the new location.

Phone numbers and (almost!) the address remain the same.

Contact:
Altronics Cannington
Albany Hwy & Wharf Sts, Cannington WA 6107
Tel: (1300) 797 007
Web: www.altronics.com.au

Micromite-Based Super Clock

By Geoff Graham

Yes, we can guess what you are thinking . . . not another clock project. But this one is special because it can show the time using either an analog or digital display. It can also track the time in up to 20 different locations, adjust each location for daylight saving and keep precise time using either a temperature-compensated real-time clock (RTC) module or a GPS module.

AS WITH a number of recent projects, our new clock is based on the Micromite LCD BackPack. This time though, we have teamed it with a very accurate real-time clock (RTC) module (or a GPS module) for basic timekeeping.

As before, it relies on the touchscreen interface of the LCD panel in order to configure and operate the unit – there are no switches or knobs. This makes it easy to build and it should take no more than an hour or so to assemble.

This is more than just a single clock; instead, it's really 20 separate clocks in one. When it's displaying the time, a simple tap on either the righthand or lefthand side of the screen switches the display forwards or backwards to the next clock.

Each clock can be configured to display the time as either an analog clock (with hour, minute and second hands), a 12-hour digital clock (with AM and PM indicators) or a 24-hour digital clock. As already indicated, each clock can be configured for the daylight saving rules applying to its particular time zone. In addition, it can be given a unique title, so that you know which location each clock refers to.

All these characteristics are independently set for each clock. So, you could have one clock showing UTC, another set for Sydney time, a third set for San Francisco, and so on. You could also have two of the clocks set to a single location with one showing an analog display and the other a digital display, so that you could quickly flip between whatever style takes your fancy. Naturally, it also shows the day and date beneath the time display.

If you have relatives in different parts of the world that you telephone regularly, this clock will be a boon. With just a prod of your finger, you can quickly see what the exact time is "over there".

As with all Micromite-based projects, the software is written using BASIC and is stored as plain text. This means that you can "get in there" and modify it to do whenever you want, if you feel so inclined. To do that though, you will need to make up a cable with

The Super Clock can display the time in any one of three formats: (1) an analog clock (with second hand), (2) a 12-hour digital clock or (3) a 24-hour digital clock. It's really 20 clocks in one and each one of the 20 possible time zones/cities can be set independently. A simple tap on either side of the screen takes you to the next clock display.

Circuit Uses Either An RTC Or A GPS Module For Accurate Timekeeping

This is the RTC (real-time clock) module that's recommended for use in the Micromite Super Clock. It employs a Maxim/Dallas DS3231 chip which can keep time to ±5s per month (or better) over a 0-40°C temperature range, while its battery back-up facility retains the time during power outages.

If you have a good GPS signal indoors, you can use a GPS module as the time source instead of an RTC. Its advantages are that you never have to set the time and it is always spot on. This VK-2828U7G5LF GPS module and the RTC module at left are available from the SILICON CHIP Online Shop.

a USB-to-serial converter, as described in the February 2016 issue.

Timekeeping

The Micromite Super Clock will work with any one of three time sources: (1) an accurate real time clock (RTC) module based on the Maxim/Dallas DS3231 chip; (2) a GPS module; or (3) the internal Micromite clock which uses a simple RC oscillator.

You can use whichever source you wish but we recommend the DS3231 RTC module. This is shown in an above photo and can be purchased on eBay for a few dollars or from the SILICON CHIP Online Shop. In fact, buying the complete module this way is cheaper than purchasing the bare DS3231 chip from a normal distributor.

The Super Clock will also work with any other RTC that's supported by the Micromite (see the Micromite User Manual for the details). However, we recommend that you use a module based on the DS3231 for this project.

The DS3231 RTC is quite advanced and contains all the necessary timekeeping electronics, including a crystal and its associated oscillator. Every 64 seconds, the chip reads the output of its on-chip temperature sensor and then uses a look-up table to determine the amount of trimming capacitance needed to compensate and bring the crystal's frequency back into line. This is automatically done without any user intervention.

The result is a specified accuracy of ±2ppm over the temperature range of 0-40°C. This is a phenomenal result and equates to about five seconds per month. And that's just the maximum error; most times the DS3231 will achieve a precision much better than that.

The DS3231 also includes what the manufacturer calls an "aging offset register" which can be used to further trim the clock's accuracy. Our Super Clock gives you access to this register, so if you are very particular and have the patience, you can tweak the clock to give even better accuracy than the standard (highly-accurate) temperature-compensated crystal timebase.

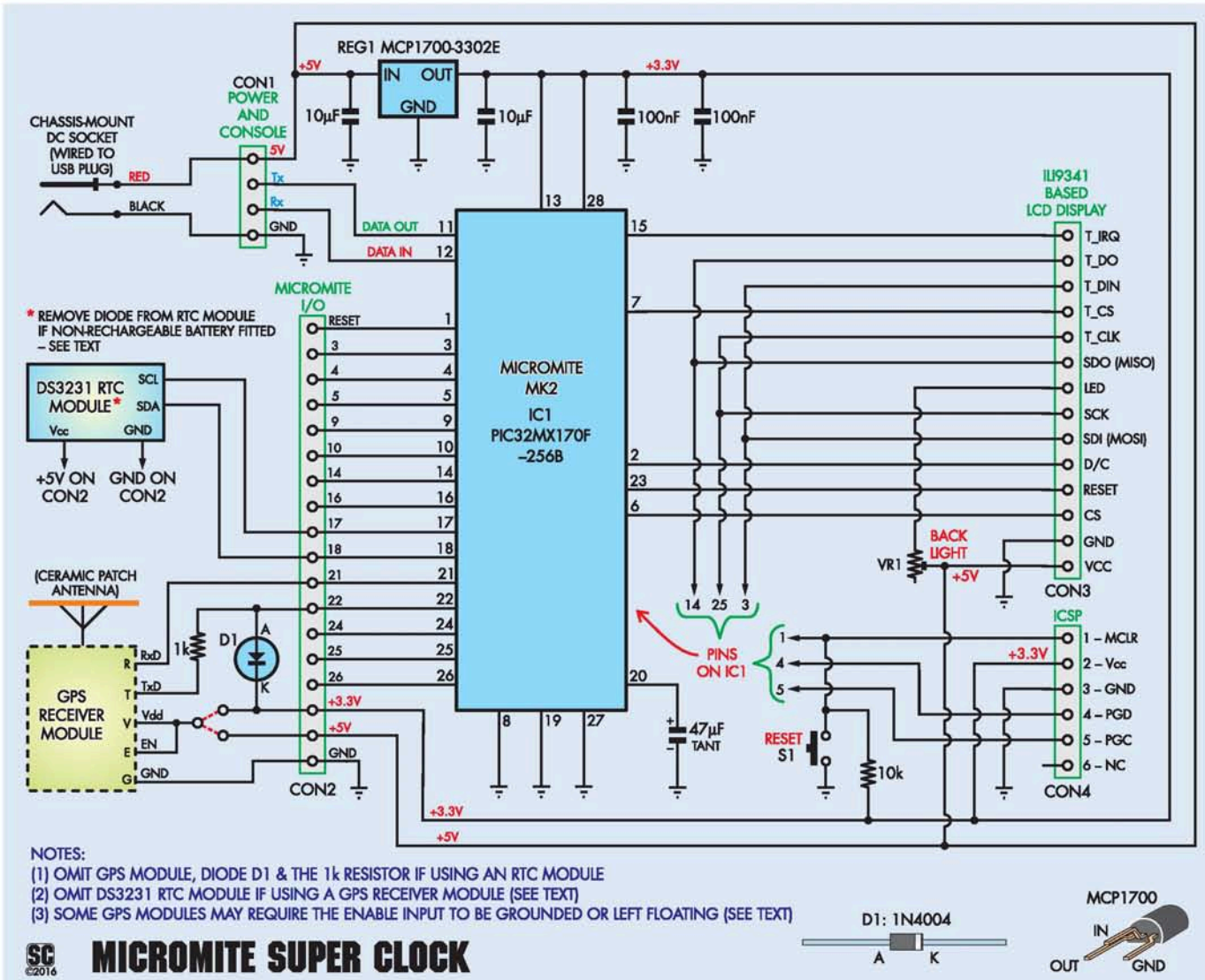
By contrast, a GPS module will be even more accurate as a time source but they are often not reliable indoors. A metal roof, rain or other factors can cause a GPS module to lose its signal. On the other hand an RTC using the DS3231 will never drop out and with its on-board battery back-up, it will continue to keep accurate time regardless of power outages.

GPS time source

GPS modules are now quite cheap and if you are sure that you have a good GPS signal indoors (or wherever the clock is to be used), one of these would make an excellent time source. The big advantage of using a GPS module instead of an RTC is that you never have to set the time. What's more, the time is always spot on since it is derived from the GPS satellites.

When power is applied, the Super Clock will first check for an RTC (such as the DS3231) and if one isn't found it will then search for a GPS module. The BASIC program in the Micromite will automatically adapt to most GPS modules on the market. This includes selecting a baud rate between 4800 and 56,300 and automatically switching between TTL and RS-232 signal levels.

If the program cannot find either an RTC or a GPS module, it will pop up a dialog box warning that neither could



MICROMITE SUPER CLOCK

Fig.1: most of the work in the Micromite Super Clock is done by IC1 which receives time signals from either an RTC (real-time clock) module or a GPS module (but not both) and drives a touch-screen colour LCD connected to CON3. The RTC module will generally be the one to use since the clock will be used indoors but a GPS module can be substituted if GPS reception isn't a problem. Power comes from a 5V DC USB plugpack charger and this directly powers the LCD, while 3-pin regulator REG1 provides 3.3V to power IC1.

The diode circled in red must be removed if a non-rechargeable CR2032 back-up battery is used in the real time clock (RTC). This diode is part of the charging circuit and removing it prevents the module from recharging the battery. Alternatively, you can leave the diode in place if a rechargeable LIR2032 battery is used – see text.

be found. When you touch the OK button on the screen, the clock will then go on to use the Micromite's internal timekeeping facility. This source is not very accurate and the time will be lost whenever the power is cycled. However, it's useful if you do not have an RTC or GPS and just want to experiment with the software.

Circuit details

Refer now to Fig.1 for the circuit details of the Micromite Super Clock. This shows the connections for both a DS3231 RTC and a GPS module but in practice only one of these is used. Omit the GPS module, diode D1 and 1kΩ resistor if using an RTC. Alternatively, omit the RTC if using a GPS module.

The DS3231 RTC module runs off 5V and uses I^2C to communicate, so it connects to pins 18 & 17 on the Micromite (IC1) which are the I^2C data and clock pins respectively. The I^2C protocol requires pull-up resistors on the signal lines and these are provided by the module, which makes it easy for us.

The alternative GPS module uses a serial interface and so it connects to pins 22 & 21 which handle the COM1 receive and transmit signals (from the Micromite's perspective). As shown, the Tx (transmit) line from the module goes to the Rx (receive) pin on the Micromite via a series 1kΩ resistor and has a clamping diode (D1) to 3.3V. These are there to protect the Micromite if the module uses RS-232 signal

levels, which can swing ±12V.

Alternatively, if you are sure that your module uses TTL signal levels, you can dispense with the diode and replace the resistor with a wire link (although leaving these parts in circuit won't do any harm).

Some GPS modules use a 3.3V supply while others use 5V. As shown on Fig.1, you can connect the module to either supply pin on the Micromite LCD Backpack.

DS3231 RTC module

As previously mentioned, the DS-3231 module can be purchased on eBay. Just search for "DS3231" and you will get hundreds of hits. The module that we purchased, as shown in the photos, is the most common. Make sure that the module that you purchase matches ours because we have tested this variant and it works well.

The RTC module is normally supplied without a back-up battery due to air-freight concerns. The battery specified is an LIR2032 which is a rechargeable lithium-ion type. However, this battery type is difficult to find in Australia.

In our application though, we don't need a rechargeable battery because the clock will spend most of its time connected to a plugpack supply. This means that the RTC will not be running off its back-up battery except during the odd power outage. However, these events are so infrequent and the current drawn by the DS3231 chip is so low that a standard non-rechargeable battery can be used instead of the LIR2032.

For this reason, if your module isn't supplied with a battery, we recommend modifying it to take a standard CR2032 battery. This type of battery is available everywhere and will last even longer than the rechargeable version (upwards of 20 years).

Modifying the RTC module to take a CR2032 battery simply involves removing a diode, as shown in the photo on the facing page. This diode is part of the charging circuit and once it's gone, the module cannot charge the battery (which could be disastrous if a non-rechargeable battery is used).

Note that the DS3231 module shown in the photos is also equipped with a 32K bit EEPROM memory chip which is not used by the Super Clock.

GPS modules

The Super Clock will work with

Parts List

Micromite LCD BackPack Unit

1 double-sided PCB, code 07102122, 86 x 50mm (for 2.8-inch LCD)
1 2.8-inch ILI9341-based touch-screen LCD, 320 x 240 pixels
1 UB3 ABS box, 130 x 67 x 43mm (Altronics H0153 or H0203, Jaycar HB6013 or HB6023)
1 laser-cut black or clear acrylic lid to suit UB3 box
1 4-pin tactile switch, through-hole hole (S1)
1 100Ω vertical-mount side adjust trimpot (VR1) (Altronics R2579, element14 9608044 or similar)
1 28-pin DIL low-profile IC socket
1 4-pin 0.1-inch male header (CON1)
1 18-pin 0.1-inch male header (CON2)
1 14-pin 0.1-inch female header socket (CON3)
1 6-pin 0.1-inch right-angle male header (CON4)
1 2.1mm or 2.5mm panel-mount DC socket (Altronics P0622 or P0623)
4 M3 x 12mm tapped spacers
4 M3 x 10mm black machine screws
4 M3 x 6mm machine screws
4 M3 x 1mm (6mm OD) Nylon washers

Semiconductors

1 PIC32MX170F256B-50I/SP microcontroller programmed with SuperClockFull.hex (IC1). Note: a PIC32MX170F256B-I/SP can also be used
1 Microchip MCP1700-3302E/TO voltage regulator (REG1)

Capacitors

1 47μF 16V tantalum or SMD ceramic (3216/1206)
2 10μF 16V tantalum or SMD ceramic (3216/1206)
2 100nF monolithic ceramic

Resistors (0.25W 5%)

1 10kΩ

RTC version

1 RTC module using the Maxim/Dallas DS3231
1 LIR2032 or CR2032 battery (see text)
4 single-pin female headers for the interconnecting leads
2 M2 x 10mm tapped Nylon spacers
4 M2 x 6mm Nylon screws

GPS Module version

1 3.3V or 5V GPS module with connecting cable
1 1N4004 silicon diode (see text)
1 1kΩ resistor (0.25W, 5%) (see text)
4 single-pin (DuPont) female headers (for interconnecting leads)

Cable Parts

1 USB cable with a male type A connector (length to suit)
1 2.1mm or 2.5mm DC plug to suit DC socket
1 4-pin 0.1-inch female header
Red & black hook-up wire

Where To Buy Parts

A kit for the Micromite LCD BackPack is available from the SILICON CHIP Online Shop. This includes a 2.8-inch touch-screen LCD panel, the BackPack PCB, a PIC32 microcontroller programmed with *SuperClockFull.hex*, all the on-board parts and a laser-cut black or clear acrylic lid with a cut-out to suit the LCD and mounting holes to suit a UB3 box (the black lid has a gloss finish on one side and a matt finish on the other).

Note that the kit does not include the box, mounting hardware, power supply, DC socket, off-board headers or any connectors or cable parts.

The BackPack PCB and a programmed microcontroller are also available separately.

RTC & GPS modules

We also have available the RTC module (back-up battery not included) plus two M2 x 10mm Nylon spacers and four M2 x 6mm Nylon screws for mounting. In addition, two different GPS modules with internal battery back-up are available and these are each supplied with a connecting cable.

Finally, suitable USB-to-serial converters are on offer and these are each supplied with a short DuPont cable to connect to the Micromite.

Browse to the SILICON CHIP Online Shop for pricing and ordering details.

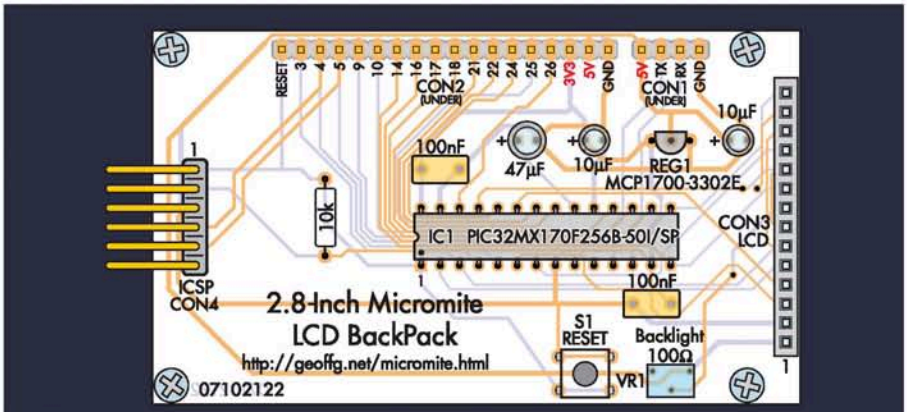
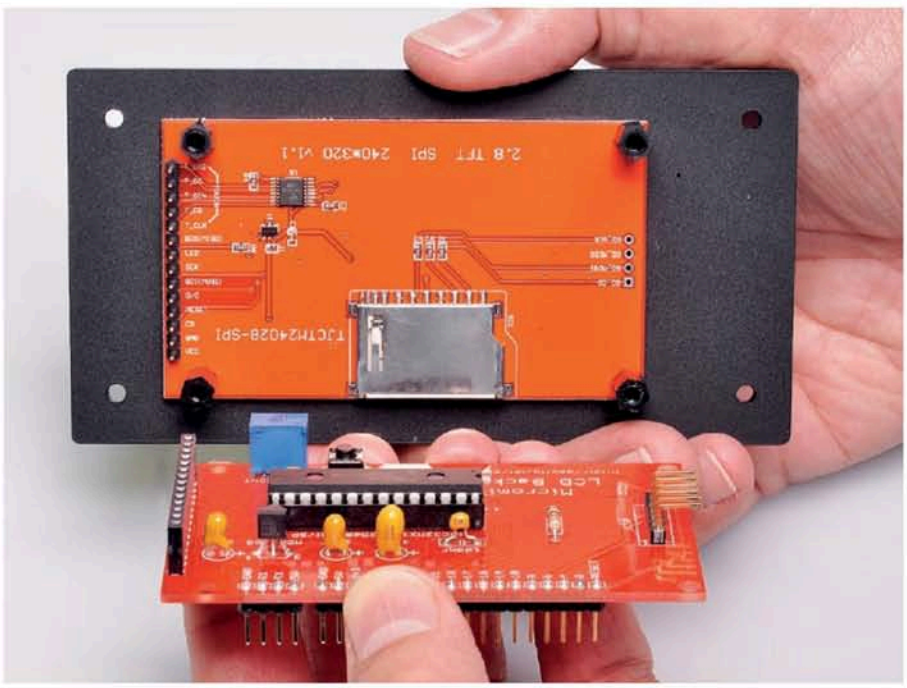


Fig.2: repeated from the February 2016 issue, this parts layout diagram shows how to build the BackPack PCB for the 2.8-inch LCD. Note that pin headers CON1 & CON2 are mounted on the rear of the PCB, while CON3 & CON4 are mounted on the top (see photos).



The colour LCD is mounted on the laser-cut acrylic lid before being plugged into the BackPack PCB. Be sure to fit the LCD to the lid with the correct orientation, so that the display is centred.

almost any GPS module, so there are quite a few units to choose from. The basic specifications required are 3.3V or 5V power, a serial interface with TTL or RS-232 signal levels and a baud rate of 4800 to 38,400.

Suitable GPS modules include the Fastrax UP501, USGlobalSat EM-408, Ublox NEO-7M-C, Ublox NEO-6M, Skylab MT3329/SKM53, V.KEL VK16HX, V.KEL VK16E and Ublox VK2828U7G5LF. The last two in this list are available from the Silicon Chip Online Shop.

All of the above GPS modules use TTL levels, so the resistor and diode shown in Fig.1 are not required (ie, delete the diode and replace the 1kΩ resistor with a link). You should also check the data sheet for the module to determine if it has any special requirements. The most common is that if it has an enable input, then this must usually be connected to the positive supply rail for the module to work.

Alternatively, some modules require the enable input to be connected to ground or even left floating, so check the data sheet carefully.

The GPS modules supplied by Silicon Chip must have their enable inputs connected to the positive supply rail and can run off either a 3.3V or 5V supply rail. They also have an inbuilt back-up battery (which some modules lack).

Construction

Construction mostly involves assembly of the Micromite LCD BackPack PCB (the 2.8-inch version is the one to use) and this should take no more than half an hour. It uses less than a dozen components and the PCB is silkscreened with the component layout and values, so it's simply a case of populating the board and plugging it into an ILI9341 LCD touch-screen panel.

The parts layout diagram for the LCD BackPack was originally published in both the February and April 2016 issues of Silicon Chip, together with other details. We're also reproducing the diagram in this issue – see Fig.2. Use a socket for IC1, take care with component orientation and note that pin headers CON1 & CON2 are mounted on the rear of the PCB (see photo at left).

A complete kit for the LCD BackPack is available from the Silicon Chip Online Shop (see parts list). This kit is supplied with SMD ceramic capacitors (2 x 10µF and 1 x 47µF), as these are more reliable than tantalums (the PCB can accept either type).

The SMD capacitors are non-polarised and can be installed either way around.

Loading the firmware

The easiest method of loading the firmware is to program the PIC32 chip with the file **SuperClockFull.hex**. This single firmware file contains everything that you need, including the MMBasic interpreter configured for the display and the BASIC program for the Super Clock. The file can be downloaded to a PC from the Silicon Chip website and to load it into the Micromite, you will need a PIC32 programmer such as the PICkit 3.

Once the chip has been programmed, it's just a matter of plugging it into its socket and you are ready to go.

The only issue that you need to be aware of is that the touch calibration in the above firmware was done with a reasonably standard LCD panel. However, yours might require recalibration if it is significantly different from the "standard" that we used.

This can be done by connecting a USB-to-serial converter to the console, halting the program with CTRL-C and re-running the calibration routine

as described in the Micromite User Manual (which can be downloaded from the SILICON CHIP website). The touch calibration procedure was also described in detail in the February 2016 issue of SILICON CHIP.

The alternative to programming the chip with the combined firmware is to load each software component separately as listed below:

- Program the chip with the file **Micromite_V5.2.hex** (the BASIC interpreter), then configure the interpreter for the display panel and touch.
- Using AUTOSAVE or XMODEM, load the file **SuperClockFonts.bas** into MMBasic and then save it to the library with the command LIBRARY SAVE.
- Using AUTOSAVE or XMODEM, load the file **SuperClock.bas** into MMBasic and issue the command RUN.

A detailed explanation of how to do this is also included in the Micromite User Manual.

USB-to-serial converters suitable for use with the Micromite are available from the SILICON CHIP Online Shop (three different types are currently on offer). All plug straight into a USB port on a PC and are supplied with a short DuPont cable to connect to CON1 on the Micromite LCD BackPack.

Pre-programmed chip

Don't want the hassle of programming the PIC32 microcontroller yourself? In that case, you can simply purchase a fully programmed microcontroller from the SILICON CHIP Online Shop. As before, you may have to go through the touch calibration procedure if your LCD panel is significantly different from the standard (although in most cases, it will be fine).

Enclosure

The Micromite LCD Backpack fits neatly into a standard UB3 enclosure. As with the Micromite Boat Computer described in April 2016, a laser-cut acrylic front panel (black) replaces the standard lid supplied with the box and this results in a neat assembly.

This panel is designed to suit the 2.8-inch touch-screen LCD panel and has the mounting holes pre drilled, along with a precision cut-out for the LCD. It can be purchased from the SILICON CHIP Online Shop.

The first stage of assembly is to attach the LCD panel to the acrylic lid using an M3 x 10mm machine screw, 1mm-thick M3 Nylon washer and an M3 x 12mm tapped spacer at each corner – see Fig.3. This arrangement ensures that the surface of the LCD sits flush with the acrylic lid. The BackPack PCB is then plugged into the LCD and fastened to the spacers by M3 x 6mm machine screws.

Note that the self-tapping screws supplied with the UB3 box to attach the lid may have to be replaced with No.4 x 10mm self-tapping screws. This could be necessary because the acrylic panel is thicker than the lid supplied with the box.

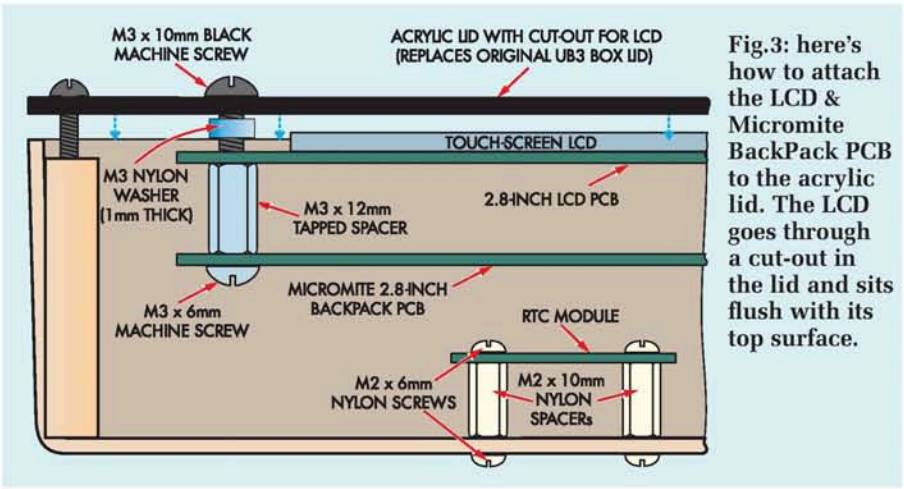


Fig.3: here's how to attach the LCD & Micromite BackPack PCB to the acrylic lid. The LCD goes through a cut-out in the lid and sits flush with its top surface.

Power supply

The unit requires a 5V power supply rated at 300mA or more. That means you can use a 5V plugpack or a USB charger. If a USB charger is used, a suitable power cable needs to be made by cutting one end off a standard USB cable (retaining the Type A socket at the other end) and soldering the free end to a suitable DC power plug. The red wire in the USB cable (+5V) should go to the centre pin of the plug and the black to the sleeve. The other two wires (the signal wires) can be cut short, as they are not used (see Fig.4).

A matching DC power socket for the incoming power is mounted on the side of the UB3 box. This should be mounted near the base of the case, so that it doesn't foul the BackPack PCB. Once it's in place, two flying leads are run from this socket and soldered to a 4-pin header socket which is then plugged into the BackPack's CON1 connector.

Be very careful here as CON1 is not polarised, so make sure that the centre pin of the power socket (+5V) connects to the pin marked with the 5V symbol on the BackPack's PCB. We speak from experience here as we accidentally connected the cable the wrong way during development.

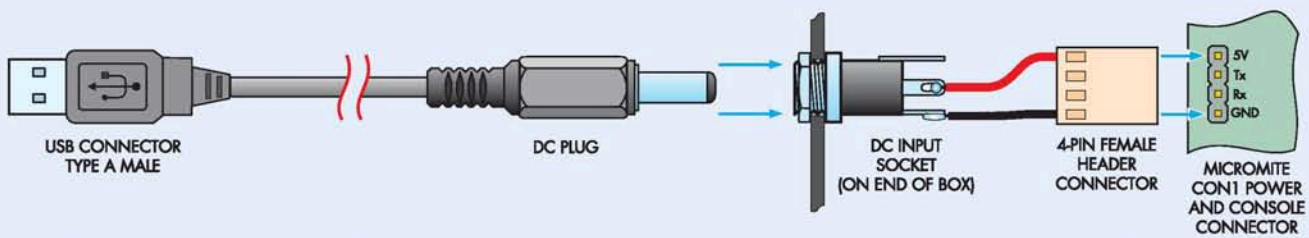
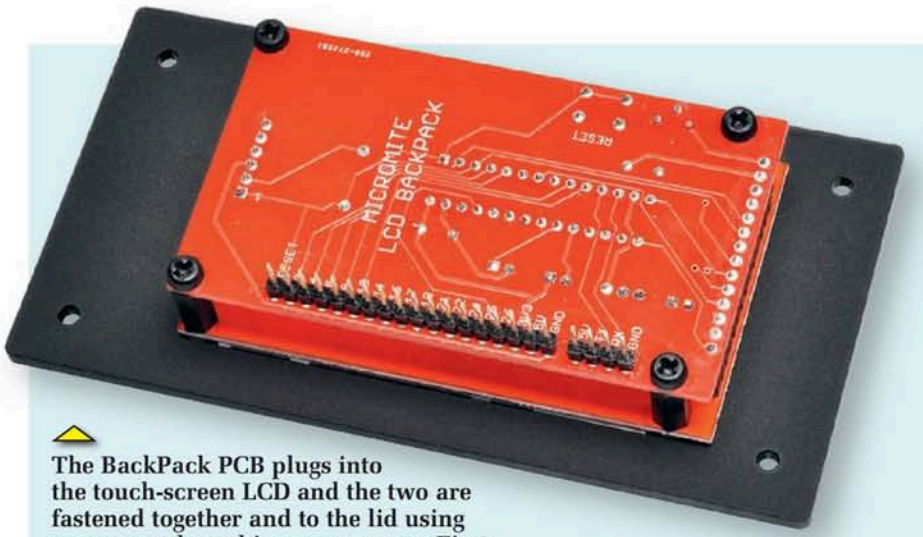
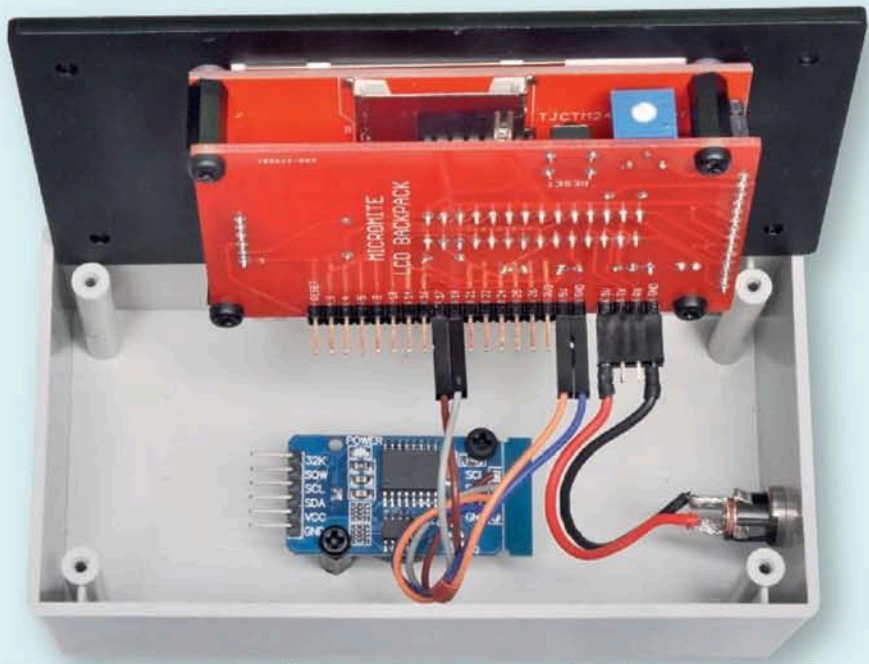


Fig.4: the Micromite Super Clock is powered from a standard USB plugpack charger. To make a suitable power cable, cut one end off a USB cable (retaining the type A male connector at the other end) and solder the red wire to the centre terminal pin of a DC plug and the black wire to the outside pin. The matching DC socket is mounted on the side of the UB3 box and is connected to a 4-pin female header which then plugs into CON1 on the BackPack PCB.



The BackPack PCB plugs into the touch-screen LCD and the two are fastened together and to the lid using spacers and machine screws – see Fig.3.



The RTC is mounted on the base of the box towards the bottom edge so that it doesn't foul CON1 & CON2 on the BackPack PCB. Similarly, the DC socket should be mounted close to the base so that it doesn't foul the edge of the BackPack PCB or CON3's soldered pin connections.

Miraculously, both the Micromite and the LCD survived but we don't recommend the practice.

RTC or GPS unit mounting

The DS3231 RTC module (if used) is mounted on the base of the UB3 box using four Nylon M2 x 6mm screws, two M2 x 10mm Nylon spacers and Nylon nuts. It must be positioned towards the bottom edge of the case (see photo overleaf) to avoid fouling CON1 and CON2 on the underside of the BackPack PCB, as these connectors extend close to the base.

Note that Nylon mounting hardware must be used due to the close proximity of the holes to the solder pads and tracks on the RTC's PCB.

Before actually fastening the RTC into position, connect four 100mm-long flying leads to its SCL, SDA, VCC & GND terminals. The RTC has solder pads for these terminals at one end and a pin header incorporating these terminals at the other and you can use either set for the connections.

The other ends of the flying leads are terminated in single-pin "DuPont" sockets to connect to CON2 on the BackPack PCB. Alternatively, you can solder the leads direct to CON2's terminals or you could use a multi-pin (10-way) header socket for the connection.

If you are using a GPS module instead of the RTC, the mounting arrangement will depend on the module. The important factor is that the antenna (the ceramic object on the top of the module) should be horizontal and pointing to the sky when the assembly is fitted to the case. The best solution is to attach it to the inside of the top of the enclosure (eg, using a thin smear of neutral-cure silicone), with flying leads running to the appropriate pins on CON2.

Using the clock

When the clock is powered up, it will first check for a connected RTC. This only takes a few milliseconds and if it is found, the clock will display the time and begin normal operation.

If an RTC is not found, the clock will display a message stating that it is checking for a GPS module. This can take up to 10 seconds as the program scans through the various possible baud rates and TTL/RS232 combinations.

If the GPS module cannot be found, the software will report this fact and you will need to sort out why it is "silent". The most likely cause is that the transmit and receive signals have been swapped. Alternatively, the GPS module may require an enable signal, as described above.

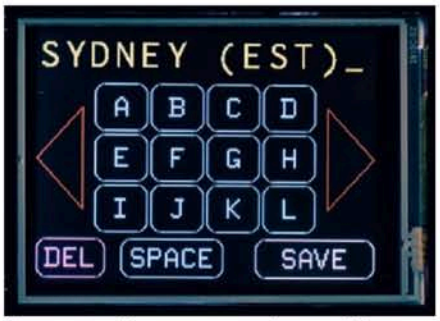
When the GPS module has been detected, the display will show the message "Searching for Satellites", which means that the module is trying to locate enough satellites to get a fix. Initially, this can take up to an hour, so place the module outdoors where it has a clear view of the sky and leave it running. When a lock has been achieved, the clock will switch to showing the time.

If neither an RTC nor GPS is found, the software will report this fact in a dialog box with an OK button. Touching this button then lets the clock function by using the Micromite's internal clock.

When the time is displayed, you can then step forward through the configured clocks by repeatedly touching the righthand side of the LCD, or step back by touching the lefthand side. Initially, there are five clocks configured and these are for UTC, Perth, Sydney, New York and Paris. By default, UTC is shown as a 24-hour clock, Perth and Sydney use an analog clock and the rest use a 12-hour digital clock. In addition,

Screen 1: tapping the centre of the LCD brings up the main configuration screen. This allows you to change the type of the clock (Hidden, Analogue, 12-Hour Digital or 24-Hour Digital) and to set the date and time. Note that if you build the GPS version, the SET DATE and SET TIME buttons will not be visible; instead, the status of the GPS module will be reported in this screen space.

Screen 2: this screen allows you to configure a particular clock (the Micromite Super Clock supports 20 different clocks). You can change the title and configure the time zone and daylight saving parameters.



Screen 3: it's easy to assign a title to a clock by pressing the SET button at the top of Screen 2 and then using this keypad.

Screen 4: setting both the time and date for the RTC version is straightforward using this keypad. When you set the time you are setting the local time and all the other clocks will then be automatically updated according to their time zone.

the correct time zone and daylight saving rules are set for each location.

Of course, these are only offered as examples and you can jump right in and change them to suit yourself. That's done by touching the centre of the LCD which will take you to the configuration screen as shown in Screen 1. This screen allows you to change the type of the clock (Hidden, Analog, Digital 12h or Digital 24h, etc), the time and settings for that particular clock, and more. All these settings are stored in non-volatile memory and automatically recalled on power-up.

At the bottom of the configuration screen are buttons marked PREV and NEXT. Using these, you can step through all 20 clocks. Note that some clocks initially have their type set to "Hidden" (clocks 6-20). This means that when you are changing the displayed clock by tapping on the screen, the BASIC program will skip over hidden clocks and wrap around at the end of the list. If you want to make a clock visible, set its type (at the top of the configuration screen) to Analogue or Digital and conversely to hide a clock, set its type to Hidden.

Underneath the clock's type is the CONFIGURE CLOCK button which allows you to set the time zone and daylight saving rules for that particular clock. The display below this button will differ depending on the time source that you are using (either an RTC or GPS module).

Set Date & Set Time

If you are using an RTC module (or the internal oscillator), this bottom section of the screen will show two buttons designated SET DATE and SET TIME. These are used to initially set the time for the RTC.

Note that when you are setting the time, you are setting the local time. For example, if the clock is showing Sydney time, you should enter the date and time for Sydney. All the other currently programmed clocks will then automatically update based on their

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Trimming The DS3231's Aging Offset Register

If you are using a DS3231 RTC module, the SET TIME button in the configuration screen has an additional feature; if you hold it down for five or more seconds, you will be taken to the DS3231's Aging Offset setting.

As explained in the text, this can be used to trim the DS3231's crystal oscillator to achieve an even greater accuracy than normal.

By default, the aging offset value is set to zero but you can plug in whatever number you wish from +127 to -127. Typically, a change of ±1 will change the clock's timing by 0.1 parts per million, which is about a quarter of a second over a month. Incrementing the number slows down the clock and decrementing it speeds the clock up.

If you want to experiment with this setting, the best method would be to set the time exactly against some standard (eg, an Internet time server) and then recheck the displayed time three months later. Simple arithmetic will then tell you the amount of trim required. You can then experiment with that value and recheck the accuracy a further three months later.

Provided you have the patience, you could get the clock's accuracy to close to spot on within a year or two!

Screen 6: an aging offset of +1 will slow the clock by about 0.1ppm while -1 will speed it up by the same amount. You can enter any number from -127 to +127.

Screen 5: setting the daylight saving rules for a clock is easy and intuitive. The clock will always increment or decrement the time by exactly one hour at 2am (non-daylight saving time) on the start or ending day specified. The only exception is the UK (time zone zero), where the time switch occurs at 1am.

respective time zone – so you only need to set the time once.

Alternatively, if you are using a GPS module, the SET DATE and SET TIME buttons will not be present because the GPS module itself supplies the exact date and time. Instead, this section of the screen will show a message reporting the status of the GPS module. Most of the time it will show "GPS Time Synchronised", which means that the GPS has a lock on sufficient satellites to get a precise time.

From time to time, the GPS could lose this lock, especially when the clock is located indoors. Rather than display an error message, the Super Clock will switch to using a timebase supplied by the crystal-controlled clock within the GPS module, which is accurate to within a few seconds per day. The clock will keep using this time source for up to 24 hours without a satellite fix and this should be enough to carry it through even the most extended glitch in GPS signal reception.

If the clock is running in this mode (ie, using the GPS module's crystal-based clock), the message on the configuration screen will show "**No sync for n.nn hrs**". This indicates that the GPS module has lost its lock on the satellites and has not been able to regain it for the past n.nn hours.

After 24 hours of no satellite lock, the BASIC program will restart the Micromite which forces it to go through the full power-up sequence, including finding the initial GPS fix. So, if you initially had the clock running successfully but then find that it is sitting there with the message "Searching for Satellites", it means that it has run for over 24 hours without a lock and you should move it nearer to a window (or install a DS3231 RTC module instead).

Daylight saving settings

The Configure Clock menu for a particular clock or location allows you to change the name allocated to that location, the time zone and the daylight saving settings – see Screen 2.

The daylight saving settings have been designed to suit most countries, although there are some that are just too complicated (for example Iran). For both the start and end of daylight saving, the setting is displayed as something like "1st Sun in Oct". By touching the SET button, you will be taken to a further screen where you can change the month of the daylight saving change, the day of the week and the position of that day in the month (1st, 2nd, 3rd or last day in the month).

The clock will always increment or decrement the time by exactly one hour at 2am (non-daylight saving time) on the start or end day specified. The one notable exception to the 2am change is the UK where the time switch occurs at 1am. The clock accommodates this special case by checking the time zone and if it is zero, it will assume that the country is the UK and the time switch will be made at 1am.

That's it, your Micromite Super Clock is complete. In practice, you will find that the menus are all simple to navigate and set-up and it will only take you a few minutes to familiarise yourself with their operation. SC

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CIRCUIT NOTEBOOK

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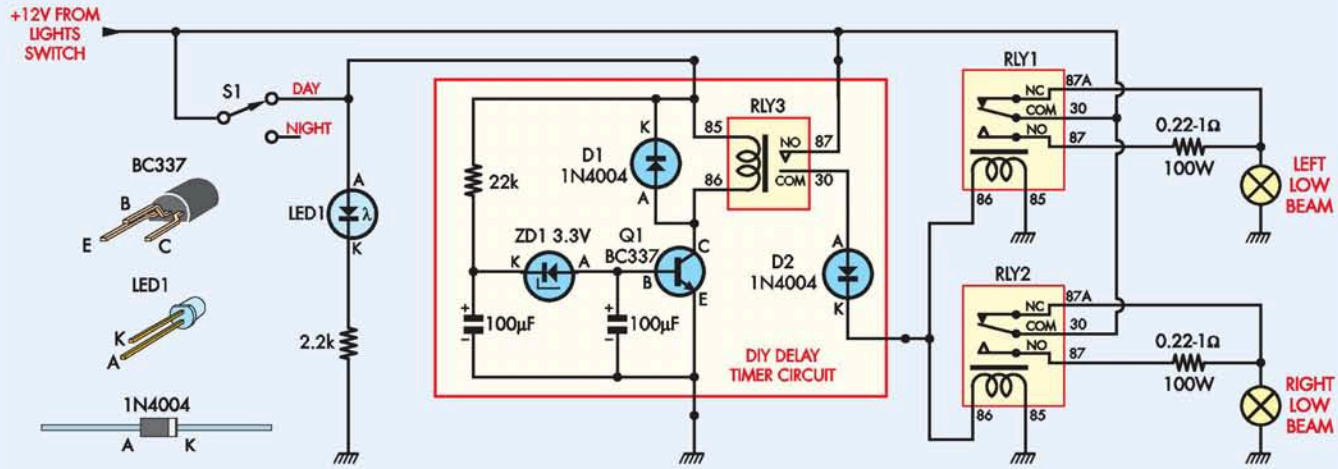

Increased life for daytime running lights

Many vehicles now have daytime running lights which are normally strips of white LEDs that are lit when the headlights are off, to make the vehicle more visible during the day, especially in cloudy or hazy conditions. Alternatively, some vehicles lack dedicated daytime running lights and use the headlamps instead. However, this can lead to the headlight bulbs failing much sooner due to their increased "on-time".

This circuit allows the headlamps to be used as daytime running lights with reduced current to extend their lifespans. While not as effective as fitting LEDs, no modifications to the vehicle body are required and new wiring need not be run. With S1 in the "NIGHT" position, the headlights operate as normal. But in the "DAY" position, 100W resistors are switched in series to reduce the brightness, extending lamp life.

Rather than switch the resistors in series with the headlamps immediately upon switching S1 or starting the vehicle, the circuit shown in the box provides a short initial delay of approximately one second. This allows the lamp filaments to heat up, increasing their resistance and reducing the initial current through the 100W resistors substantially; the lamp inrush current is typically around 20A while steady-state operating current will be closer to 4A. This prevents failure of the 100W resistors due to high instantaneous dissipation at lamp switch-on.

The timer works as follows: when power is applied via S1, the 100µF capacitors charge up via the 22kΩ resistor. ZD1 increases the capacitor charge voltage required to forward bias the base of transistor Q1.

After approximately one second, Q1's base voltage reaches around 0.65V, switching it on. RLY3 then closes its contacts, powering the two larger relays, RLY1 & RLY2. These must also be automotive types, capable of handling the headlamp inrush current of around 20A. Alternatively, a single, higher-current relay could be used to switch power to both lamps.

LED1 indicates when the headlamps are in daytime mode and should be positioned so it is very obvious if it is lit at night, reminding the driver to switch the lamps back to their full brightness mode by putting S1 in the "NIGHT" position. LED1 also serves as a discharge path for the 100µF timing capacitor when power is removed.

Note that this circuit assumes that the headlights are switched on the positive side. If your vehicle switches the negative side instead, connect the COM terminals of RLY1 & RLY2 to chassis and change S1 to switch the negative supply connection for the timer circuit.

Also, while 1Ω resistors are close to the ideal value to reduce power to typical 55W headlamp bulbs, the resistance may be high enough to trigger a headlight fault warning in some vehicles. Using 0.47Ω resistors makes this much less likely and even lower values can be used (down to 0.22Ω) if necessary, although lamp life extension will not be as good.

Lee Bourgious,
Mittagong, NSW. ($60)

MISS THIS ONE?

Published in Feb 2013

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Speedometer driving circuits

These circuits simulate the signal produced by a speedometer sender unit, allowing a speedometer to be tested and/or calibrated without needing a moving vehicle. Typically, there are two types of sender: Hall Effect and reluctor. Hall Effect sender units can be recognised by the use three connections: 0V, signal and positive supply voltage. By contrast, the reluctor sender unit has just two connections.

The first circuit at right is suitable for simulating a Hall Effect sender, which has an open-collector output. Normally, the pull-up resistor is housed within the speedometer and pulls the sender's output up to 5V or so (the speedo's own supply voltage).

The signal source can be virtually any audio signal generator that can produce a 1V peak square-wave signal (ie, 2V peak-to-peak/RMS). The signal generator switches on NPN transistor Q1 during positive excursions, by forward-biasing its base-emitter junction through a 1kΩ current-limiting resistor. The base junction is clamped to -0.7V or so during negative excursions by diode D1, with the same 1kΩ resistor limiting the current to a safe level.

Note that the signal generator ground terminal connects to the speedometer's 0V input. Note also that the pull-up resistor may be incorporated within the speedometer sender. In that case, you will need to add your own pull-up resistor, between the speedometer's positive supply and the collector of Q1. A 10kΩ resistor should be suitable.

By contrast, a reluctor is composed of a coil and magnet. Iron vanes on a wheel located in the gearbox rotate past the sensor, resulting in an AC voltage output. These are trickier to simulate as one side of the sensor is typically connected to a half supply rail provided by the speedometer (generally about 2.5V). The signal then varies above and below this level.

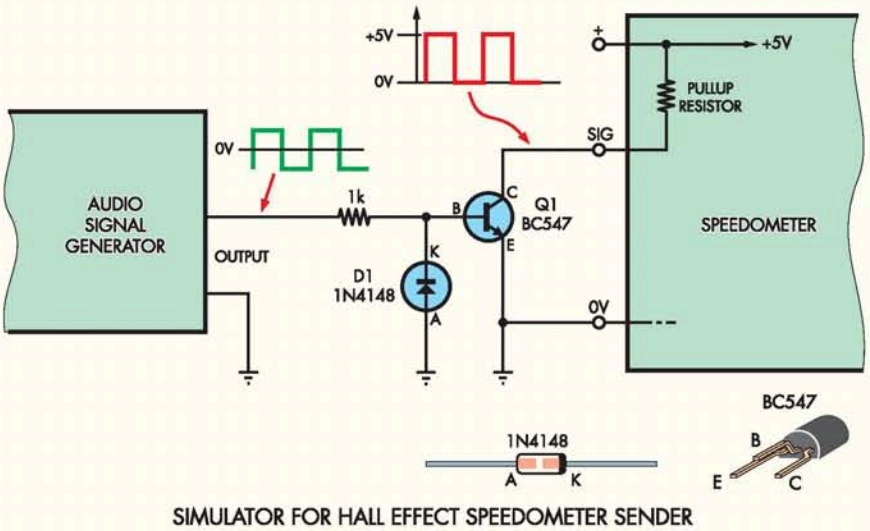
A reluctor sender can be simulated by connecting the output ground of an audio signal generator to this half-supply reference point with the generator output then going to the speedometer's signal input. But for this to work, the generator must have a floating supply separate to the vehicle's supply (eg, its own internal battery).

A 600Ω (or 560Ω or 620Ω) resistor may be required across the terminals. This ensures that the DC level of the speedometer's signal input is close to its reference voltage, otherwise a fault code may be issued. Some signal generators will already have a 600Ω output resistance and so the resistor will not be required. Check with a multimeter first.

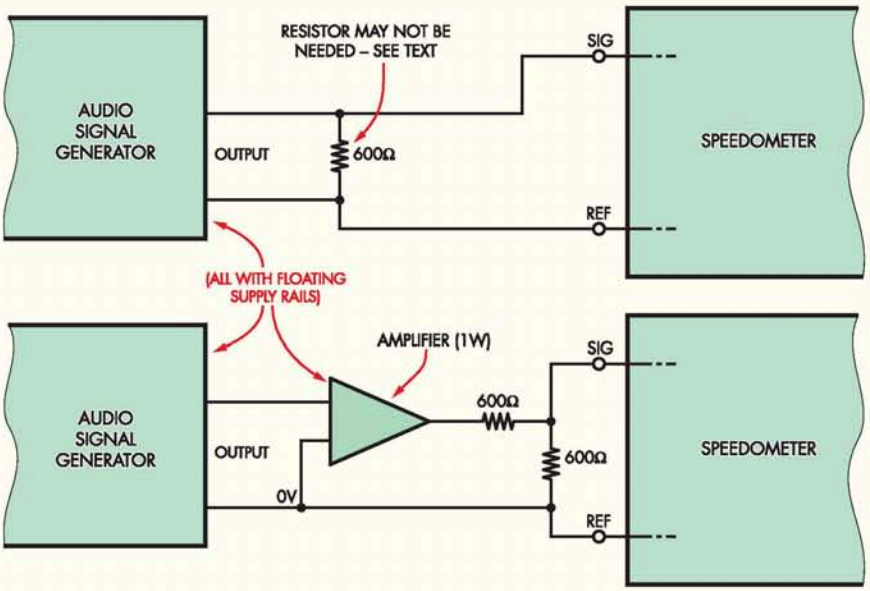
Some audio signal generators may not be able to produce enough voltage swing to operate a speedometer. In this case, you can use a 1W audio amplifier to increase the swing, again with a floating supply. The speedo may require 5V peak-to-peak or more. A 600Ω resistor should be connected in series with the amplifier's output as a current limiter, along with a 600Ω load resistor as described earlier.

For all the above simulators, the typical frequency required will be around 100Hz for a 100km/h speedometer reading.

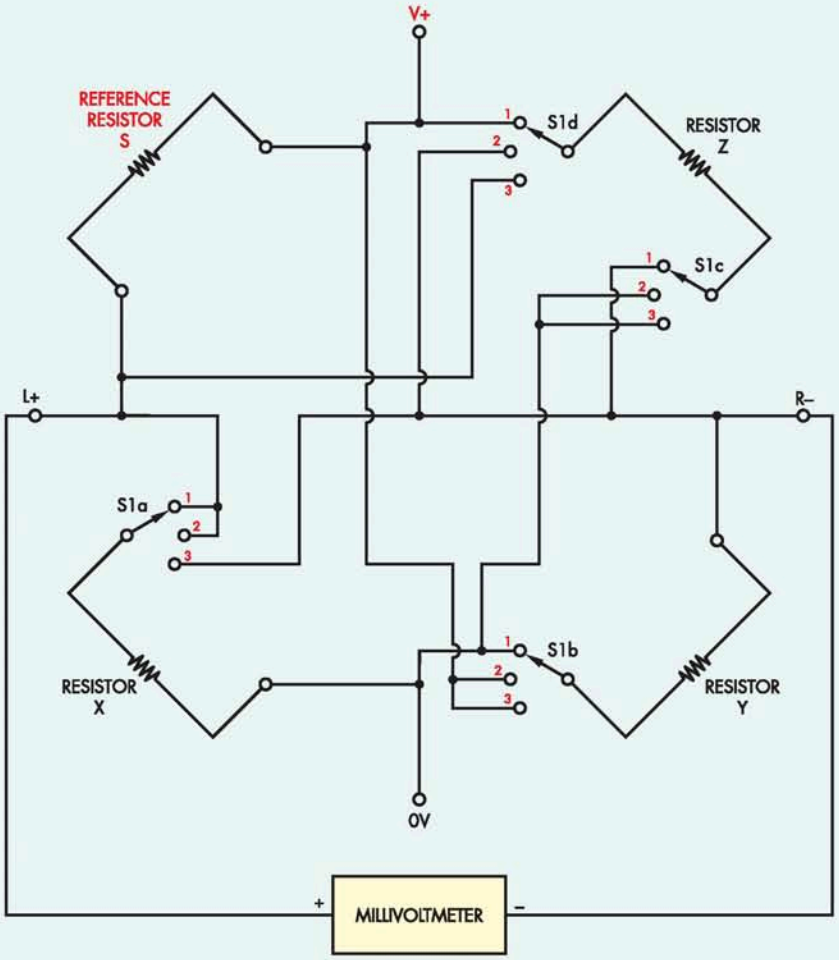
John Clarke,
Silicon Chip.

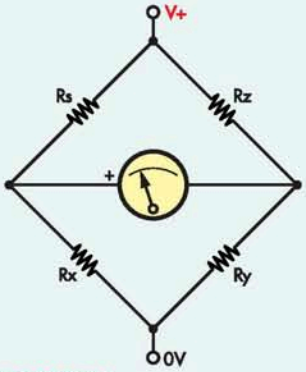


SIMULATOR FOR HALL EFFECT SPEEDOMETER SENDER

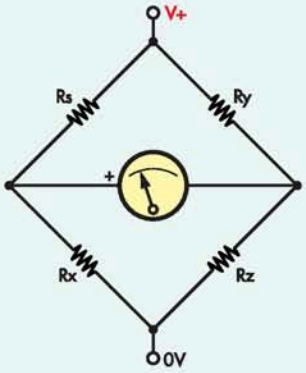


SIMULATOR FOR 2-WIRE (RELUCTOR) SPEEDOMETER SENDER

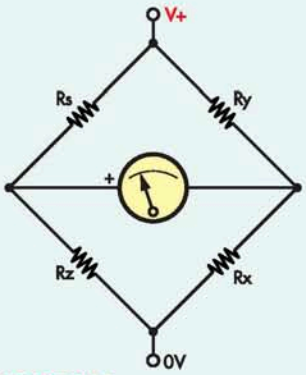




SWITCH POSITION 1



SWITCH POSITION 2



SWITCH POSITION 3

Precision resistance matching bridge

This Wheatstone bridge arrangement allows similarly-valued resistors to be rapidly matched. It can show the difference in value between one reference resistor (labelled as the standard) and three other separate resistors at the one time. It has been used to match a set of old 30kΩ Manganin resistors to 1ppm for calibrating a Kelvin-Varley divider and so is capable of any needed precision.

The Wheatstone bridge comprises four resistors with voltage applied across the top and bottom of the bridge and with a voltmeter across the two side junctions. The circuit shows the arrangement with a 4-pole 3-way switch used to provide the three independent configurations of the resistors, as shown on the right-hand side of the diagram. In each case, the standard resistor is labelled as R_S while the remaining resistors are R_X, R_Y and R_Z.

For each switch position, the voltage between the left (L) and right (R) positions is measured. The difference in ohms between the standard R_S and the other resistors is then calculated.

For R_X, the difference in ohms from R_S is calculated as: 2 x Rs x (voltage measured in position 1 + voltage measured in position 3) ÷ V+

For R_Y, the difference in ohms from R_S is calculated as: 2 x R_S x (voltage measured in position 2 + voltage measured in position 3) ÷ V+

For R_Z, the difference in ohms from R_S is calculated as: 2 x R_S x (voltage measured in position 1 + voltage measured in position 2) ÷ V+.

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Turntable mods to lift tonearm on power cut

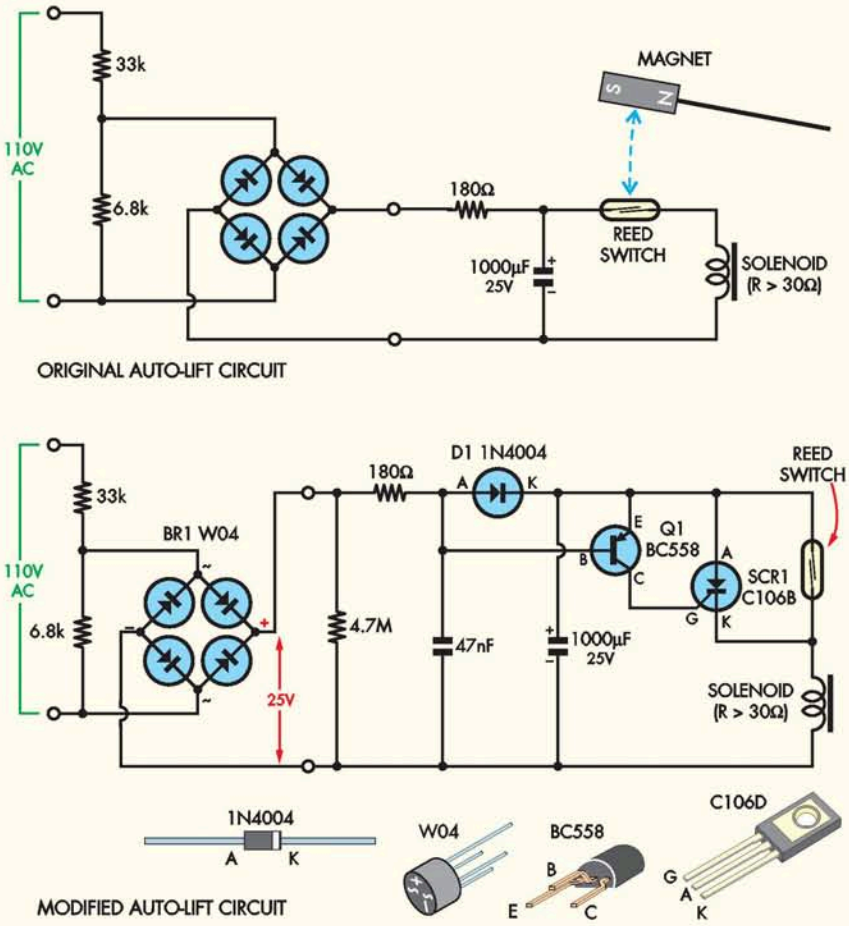
I have a Connoisseur BD2/A turntable which I bought around 1980 and it has an auto-lift feature which raises the tonearm once it reaches the end of a record. I wrote about some of the repairs I made to the turntable in Serviceman's Log, May 2016. I also made the modification shown here so that the tonearm automatically lifts if the platter motor is switched off with the stylus in the groove.

The auto-lift function is initiated by a reed switch located underneath the turntable, which normally happens when the stylus reaches the end of a record. As shown, the reed switch dumps the charge in a 1000µF capacitor through a solenoid which lifts the tonearm. That capacitor is charged from a 110VAC source through a resistive divider, bridge rectifier and an additional current-limiting resistor. The capacitor charges to around 20V DC and the resistors limit the charge current to around 3mA.

My modified circuit retains the existing components but adds several new ones. The 1000µF capacitor is now charged via diode D1 but this has very little effect on its final voltage and the reed switch being closed still triggers the solenoid as usual.

The added 47nF capacitor is also charged to a similar voltage, just slightly higher than the 1000µF capacitor due to the forward voltage of D1. When the platter motor power is cut, this 47nF capacitor discharges through the 4.7MΩ resistor but D1 prevents the 1000µF capacitor from discharging through the same path.

As a result, the 47nF capacitor voltage quickly drops below that of the 1000µF capacitor, causing PNP transistor Q1's base-emitter junction to become forward-biased, switching it on. This causes current from the 1000µF capacitor to flow into the gate terminal of SCR1, triggering it. SCR1 then effectively shorts out the reed switch, discharging the 1000µF capacitor through the solenoid, lifting the tonearm. Thus, when the platter motor is switched off, the result is the same as when the needle reaches the end of the LP, ie, the tonearm is lifted off the platter.



Gavin Krautz,
Morningside, Qld. ($70)

Editor's note: this circuit assumes a floating 110VAC supply derived from a transformer. **DO NOT run this circuit directly from a 110VAC mains supply as this will cause the entire circuit to operate at dangerous voltages.** Do not attempt this modification unless you know what you are doing.

There is no need for a regulated power supply although it must not drift between measurements of the V+ supply and the bridge offsets. The bridge should be enclosed in a shielded box with only the eight terminals for the resistors exposed.

If high precision is required, the following is recommended: use an 8-pole switch, with the extra poles used at the unswitched ends of the resistors (ie, with the three switch positions in parallel); and use symmetrical wiring, making all the connections of equal length, with the same number of soldered joints and the same type of wire.

This ensures that thermal EMFs and wiring resistances will be the same for all arms of the bridge. The extra switch poles mean that the current for each resistor flows through two switch contacts. A switch reversing the excitation voltage could also be used and the errors averaged between one polarity measurement and the other. This allows thermoelectric effects to be accounted for.

Note that the voltmeter resolution will affect the accuracy of the resistor error measurements. The voltmeter calibration is not critical but the display resolution is important.

Assuming the V+ supply is 1V, to find the difference between the standard resistor and any others to a resolution of 1ppm, the meter will need to measure the 1V supply and the Wheatstone Bridge terminals to a resolution of 1µV. For 0.1% resistor matching, the meter needs to have a resolution of 1mV.

Variations in switch contact resistance should also be considered when applying this method to low value resistors.

Andrew Johnson,
Crawley, WA. ($40)

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M 8894

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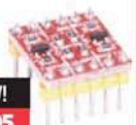

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B 0091

Add bling to your hifi amplifier!

Pt.2: By Nicholas Vinen

100dB Stereo LED Audio Level/VU Meter

Last month, we introduced our new Audio Level/VU Meter which uses 80 high-brightness SMD LEDs to give a colourful dual-bargraph display showing average and/or peak audio levels. It has a number of useful features such as adjustable dynamic range, reference level and LED brightness. This article deals with assembling it and explains how to set it up and use it.

AS DESCRIBED in Pt.1 last month, the meter is based on a 32-bit PIC processor driving 88 bright SMD LEDs. It has an analog front end with the processed signals being delivered to the PIC's analog inputs to be converted to digital format by its internal ADC so that the signals can be analysed by the software.

Having gone over the details of its operation, let's now get straight into building the PCB.

Construction

The PCB overlay diagram is shown in Fig.4. All parts are fitted to this board, with most being surface mount devices (SMDs). The exceptions are connectors CON1-CON4 and switches S1 & S2. All of these through-hole components can be mounted off-board (eg, chassis-mounted) and connected via shielded cables (for CON1 & CON2) or twin lead (eg, figure-8, for CON3, S1 & S2) – see below for more details. If doing this, these components are left off the PCB and PC stakes can be fitted to the test points near the DC socket for wire termination.

Start construction with the SMD components. It's best to fit IC1 first, as it has the finest lead pitch of any of the SMDs on this board, although it is not too daunting as the pins have a relatively generous 0.8mm pitch on a 10x10mm package.

There are various valid techniques for hand-soldering SMDs as well as other methods involving toaster ovens, frying pans and so on. Our preferred technique (as long-time readers will no doubt be aware) is to first place a small amount of solder on one pad, heat this while sliding the part into place, check its orientation and that all the pins are correctly centred over their pads, then solder the remaining pins before finally refreshing the initial joint.

Take your time doing this with IC1 and be careful to ensure that its pin

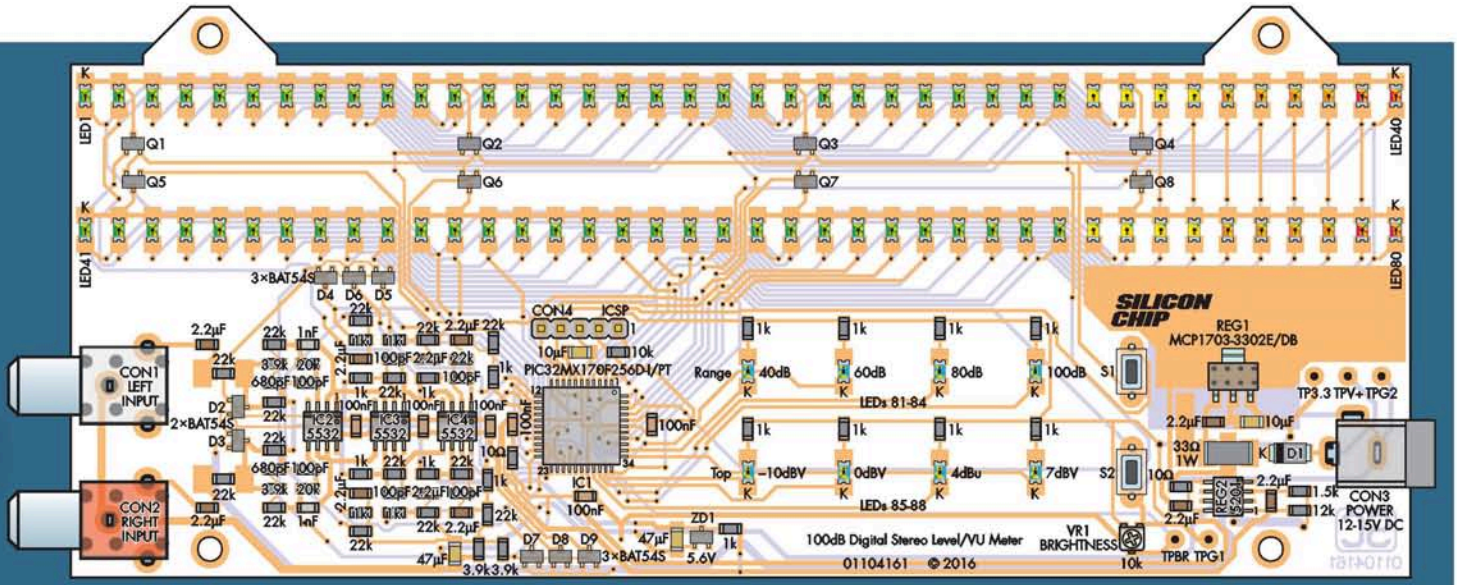


Fig.4: follow this parts layout to build the Stereo Level/VU Meter. Most parts are SMDs and all are fitted to the top side of the board. Microcontroller IC1 has a 0.8mm pin pitch, while the remaining parts have wider-spaced pins. Take care when fitting the LEDs to ensure they have the correct orientation and that they are lined up neatly.

1 dot is in the location indicated on Fig.4 and that all its pins are nicely aligned before soldering more than one. Spreading a thin layer of no-clean flux paste over the pads aids in soldering. Don't worry too much about bridging the pins – in fact, it's easier if you simply place some solder on the iron and run it along the side of the IC to solder a whole bunch of pins at once.

You can then clean up the bridges by adding a little extra flux paste and then gently applying some solder wick and heating it until the excess solder flows off the IC pins and into the wick. Repeat until all the pins have been properly soldered. It's a good idea to then inspect the joints under a magnifying lamp after cleaning off any flux residue with pure alcohol or a specialised flux cleaning solution.

The remaining ICs, including REG1 and REG2, can be soldered using a similar technique although their pins are far enough apart to be soldered individually. Note that if IC2, IC3, IC4 or REG2 lack a dot to indicate pin 1, you should be able to identify it as being on the chamfered side of the package. For REG1, it's easiest to solder the smaller pins first and then the tab, as the tab will require significant heat (and thus time) to solder. It helps to spread some solder paste on the large pad for the tab before sliding REG1 in place.

With the ICs soldered, follow with D1 and ZD1, ensuring that D1's cathode stripe goes to the left as shown in Fig.4. You can then solder transistors Q1-Q8 and diodes D2-D9 in place, making sure you don't get them mixed up as they are in identical packages. Follow with all the capacitors and resistors, none of which are polarised. Note that the resistors will have value codes printed on top (eg, 223 = 22kΩ) while the capacitors will be unmarked.

The 10µF and 47µF capacitors may be a larger size than the others and larger pads are provided to accommodate these. Similarly, the two 22kΩ resistors in the input divider are larger than the others (in case they have to dissipate more power in a fault condition) and the 33Ω 1W resistor is larger again.

Next fit VR1, unless you are going to mount an external brightness pot. Try to avoid getting solder on its metal body as the flat pins cover most of the pads and are quite close to the body.

Installing the SMD LEDs

In terms of SMDs, that just leaves the LEDs. The first job to do is to check their polarity. All the LEDs we used (which are the same types as we will be supplying) have green cathode dots. However, some LEDs have green anode dots so you should confirm this. To do this, set a DMM on diode test mode and touch the probes to either side of one of the LEDs. If they make good contact and the polarity is correct, the LED will light up. In this case, the red lead is on the anode.

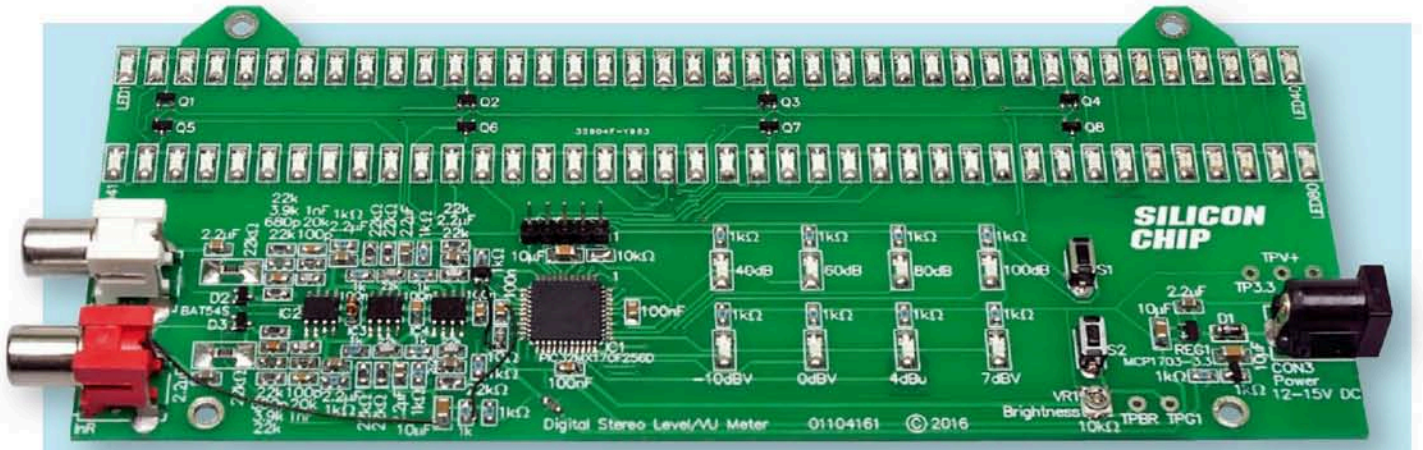
If nothing happens, try flipping the LED around (or reversing the leads). You should get it to light up with one polarity, although it's possible some DMMs will not have enough bias voltage to light some LEDs (eg, blue).

It's a good idea to do a reasonably neat job of soldering LEDs81-88, centring them on their pads and making sure they are not fitted crookedly, but it's absolutely critical for LEDs1-80 if you want the bargraphs to look good. The first trick to doing a neat job is to solder all the LEDs at one end and inspect them critically before soldering the other ends. This gives you the possibility of nudging any LEDs which are misaligned compared to the others.

Don't forget that the cathodes for LEDs81-88 face the bottom of the PCB while the cathodes for LEDs1-80 face the top. Reversing the polarity of LEDs en masse is possible but time consuming!

We aligned the main bargraph LEDs by hand and while close inspection reveals that a few are slightly askew, this really isn't obvious when viewing the device during operation. If you want them perfectly aligned, the best solution may be to clamp a straight edge parallel to the top of the PCB so that you can push the LEDs up against it and have them located evenly between the pads and square with them.

It would then just be a matter of sliding them until they were centred and soldering the far side. Once they're all in place, you can remove the straight edge and solder the other ends. Note that SMD LEDs are easier to solder if you've first applied a little flux paste to the pad and/or terminal. Don't overheat the plastic lenses though, they can be burnt quite easily – we strongly ad-



This view shows the prototype PCB assembly. Take extra care when installing the LEDs and ICs to ensure they are all orientated correctly. We used green LEDs for LEDs 1-30 & 41-70, yellow for LEDs 31-34 & 71-24, amber for LEDs 35-38 & 75-78, red for LEDs 39-40 & 79-80 and blue for LEDs 81-88.

vise against using a hot air reflow tool in their vicinity.

Through-hole parts

Assuming you are fitting them, push switches S1 and S2 down fully onto the PCB and solder their leads. Otherwise you could fit PC stakes to their mounting pads, or simply solder wires direct to the PCB. DC connector CON3 should also be pushed down fully before soldering or, as stated earlier, connect supply leads to TPV+ and TPG2.

If your microcontroller has been supplied pre-programmed you don't need to fit CON4. Otherwise, solder it in place in the usual manner. Alternatively, it can later be fitted to the rear of the PCB if necessary.

That just leaves RCA sockets CON1 & CON2. If using the RCA sockets supplied by SILICON CHIP, you will need to bend the two side pins out to make them fit the pads (see photos of our prototype). We supply them in a pack of four including white and red; unfortunately, white RCA sockets are hard to find. Alternatively, you could use different colours (eg, red & black). Regardless, make sure they are pushed down fully and properly perpendicular to the edge of the board before soldering the pins.

If you don't want to use sockets, solder the braid of a length of shielded cable to the central pin and the signal wire to the terminal closer to the top edge of the board.

Programming the micro

If you don't have a pre-programmed micro, you will need a PICkit 3 (or equivalent) and the HEX file from the SILICON CHIP website. The Microchip MPLAB Integrated Programming Environment is a free download from the Microchip website. Enter the chip type, connect to the programmer, then go into advanced mode and under "Power" options, enable "Power Target Circuit from Tool".

You can then go back to "Operate", click on the "Browse" button next to "Source" and select the HEX file. Plug the PICkit 3 into CON4 on the PCB, with the triangle on the programming tool lined up with the pin 1 indicator on the PCB. Press the "Program" button and after 20 seconds or so it should announce that the chip was successfully programmed and verified. You can then unplug the tool.

If programming fails, check that the solder joints on IC1 are OK, along with those on the four capacitors surrounding it. Check also that you have enabled power from the PICkit 3 (at 3.3V or so) and that it has been correctly plugged into CON4 and is not offset or reversed.

Chassis-mounting connectors and/or controls

If fitting the VU meter assembly inside a power amplifier chassis, you may be able to do without connectors altogether, although they do make installation somewhat more convenient. In this case, CON1 and CON2 can be wired directly to the amplifier outputs. Similarly, CON3 can be omitted and TPV+/TPG2 wired directly to a regulated 12-15V DC supply within the amplifier.

Be careful to avoid creating a ground loop involving the signal grounds and power ground connections. Ideally, the power supply should be floating and if necessary, derived from a dedicated transformer secondary winding (or separate transformer).

We also recommend that you avoid using a DC supply that's also used to power a preamplifier. That's because the pulsed current drawn by the VU meter might affect the preamp's performance. The ideal solution is a small, separate rectifier/filter/regulator based on, say, a 7812 and powered from a separate low-voltage winding on the transformer. It only needs to be able to deliver 150mA.

If you can't use a floating supply, make sure there is no difference in ground potentials between the supply for the VU Meter and the amplifier outputs. Also, if the amplifier outputs are bridged, do not connect the negative output to the inputs of the VU Meter. Instead, wire these inputs to ground and keep in mind that the input signal swing will be half of the amplifier output swing (ie, 3dB lower).

Switches S1 and S2 may be mounted off-board if desired, so that they are accessible outside the chassis, although in cases where the inputs are hardwired to amplifier outputs, you probably won't need access to S2. In this case, the unit will normally be used with a fixed reference level of +7dBV.

VR1 can also be mounted off-board so that the brightness adjustment can be easily accessible. Any potentiometer of approximately the same value should be fine. Wire its wiper to TPBR, the bottom of the track (anti-clockwise) to TPG1 and the top of the track (clockwise) to TP3.3.

Testing

Ideally the unit should be powered for the first time with a current-limit-

Table 1: Display Modes			
Mode	Averaging	Display	LEDs Flashing
1 (default)	RMS	average bar + peak dot	LED81, LED85
2	RMS	average bar only	LED81, LED86
3	N/A	peak bar only	LED81, LED87
4	VU-style	average bar + peak dot	LED82, LED85
5	VU-style	average bar only	LED82, LED86

ed power supply. If you have a bench supply, set it for 12V with a limit of 200mA. Otherwise, you could use a 15V regulated (or 12V unregulated) plugpack wired with a 47Ω 5W resistor in series. Apply power and check that LED81 (40dB) and LED86 (0dBV) are lit. A quick press of S1 and S2 should cycle the lit LEDs.

The current drain should be around 50mA. If using a series resistor, you can check this by measuring the voltage across the resistor (eg, ~2.35V across 47Ω). When LED84 (100dB) is lit, you may find some of the bottom segments of the bargraphs light up. This is normal as the inputs are currently un-terminated.

Check the voltage between TP3.3 and TPG2. It should be between 3.28V and 3.32V; a little lower or higher is OK. You may also wish to check the voltage across the 2.2µF capacitor to the right of REG2; it should be between about 10.8V and 11.5V. If it's above 11.2V, you may wish to consider shunting the 12kΩ resistor with a 470kΩ resistor (which can be soldered on top) to reduce it, to ensure the regulator won't enter drop-out with a supply voltage very close to 12V.

If using a series resistor to limit current, this will not permit the unit to draw enough current to light up all LEDs and continue to operate normally. So short out the resistor before performing further tests.

If you switch off the unit and hold down S1 while applying power, all LEDs will light up. You can use this feature to check that they are all soldered properly and operating normally. If any do not light up, check their soldering and orientation. If you need to remove a LED (eg, if it is faulty), you can do so by alternately heating the two pads until it lifts off. Then add a little flux paste and use solder wick to remove the remaining solder from the pad(s).

Assuming all LEDs are working, release S1 to exit LED test mode, then connect a signal source to the unit. You can then check that the bar displays are working normally and respond to presses of S1 and S2 as expected (use the instructions below as a guide).

Operating instructions

The Stereo LED Level/VU Meter will fire up as soon as it has power and resumes the last used mode. You only need to use the controls to switch modes or to perform calibration.

A brief press of S1 will cycle to the next meter scale. The default is 40dB. Pressing S1 will change this to 60dB, then 80dB, then 100dB, then back to 40dB. The decibel level of the top-most segment remains the same, ie, this lights when the input signal reaches the reference level which is 0dBV by default. Pressing S2 cycles through the four available reference level options.

Initially, the display shows the average level as a bar, with a dot indicating the peak level. In some cases, the peak dot may coincide with, or be just above, the top of the bar so it will not be visible. Normal program material will typically have a 5-15dB difference between the average and peak, so there will normally be a significant separation.

You can change to a different display mode by pressing both S1 and S2 simultaneously, then quickly lifting off both. Refer to Table 1 for a list of the five available modes.

To adjust the bar brightness, simply rotate VR1. Note that the specified SMD trimpot does not have an end-stop so if you turn it too far in one direction it will "wrap around". Note also that the minimum brightness setting gives about 5-10% duty cycle, which may not be all that dim, given how bright modern SMD LEDs are.

Further adjustments can be made using switches S1 & S2 to access the various set-up modes described below. The method to access these modes is summarised in Table 2.

Noise nulling

The input noise level of our proto-

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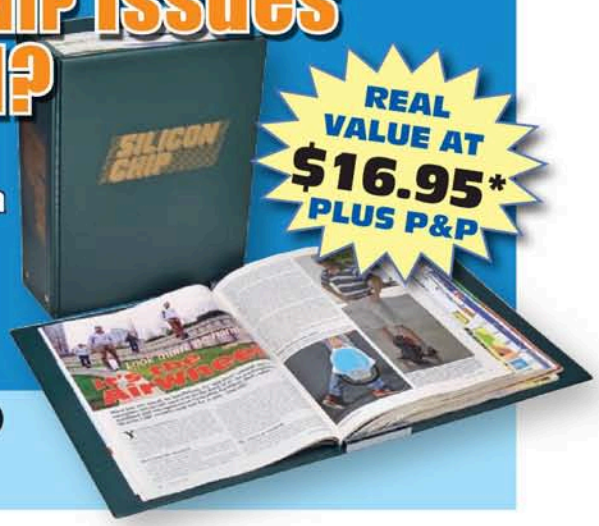

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Table 2: Summary Of Set-Up Modes

Setting	Action
LED test	Hold down S1 while powering on
Relative LED brightness adjustment	Hold down S2 while powering on
Set noise null levels	Hold down S1 after power on for at least 0.5s
Cancel noise null	Hold down S2 after power on for at least 0.5s
Change average/peak hold period	Hold down S1 after power on, press S2 once (LED81 flashes), release S1
0dB calibration with reference signals	Hold down S1 after power on, press S2 twice (LED82 flashes), release S1
0dB calibration without reference signals	Hold down S1 after power on, press S2 three times (LED83 flashes), release S1

type unit is around -100dBV although this depends on how the inputs are terminated, the LED brightness setting, how quiet the power supply is, etc. With the unit set to 100dB dynamic range, a 7dBV reference level and average-only display, both bars should be totally unlit. However, if the meter is set to 100dB dynamic range and you select a lower reference level or enable peak metering, some of the segments will be lit all of the time, even with no signal.

If your signal source produces some noise, and most do, it will likely increase the no-signal reading and may even light one or more segments on the less sensitive ranges if it is particularly noisy.

In either case, you can null out the noise to give a blank display with no signal by simply hooking the signal source up, switching both units on and, with no audio output, holding down S1 for a little over half a second. LED84 ("100dB") will flash and the bars should drop to zero. If they don't, try again. Now introduce a signal and verify that the meters still light up as expected.

This works by storing the average and peak level measured when S1 is held down and these readings are subtracted from future measurements. If you want to cancel it and go back to showing the raw (unadjusted) reading, simply hold down S2 for at least half a second. LED88 ("7dBV") will flash and the display will go back to how it was before.

0dB calibration

If you want the unit to handle signals above 2.33V RMS, you will need to change the input divider. But if you want to make a small adjustment, eg, to set a reference level other than one of the four existing options, or to compensate for resistor error (including differences between the two channels), you can do that using the software's calibration feature.

A new reference level can be set for each channel in each of the four available "slots" corresponding to LEDs85-88. When you set a new reference level, it overrides the pre-existing level for that slot. Before you set a new reference level, use S2 to select the slot in which you want to store the new level(s).

The easiest method is to feed a signal into both channels at the level you want for full scale, then switch the unit on with S1 held down. Before releasing S1, press S2 twice. LED86 will flash a few times. The signal level for both channels will be used as the new 0dB reference level for the currently selected slot.

Alternatively, if you do not have a signal generator that can produce the appropriate levels, you can adjust the reference level for a slot incrementally, in 0.1dB steps between -20dBV and +7.3dBV. Instead of pressing S2 twice before releasing S1, press it three times. LED87 flashes instead. Now, the left channel display (top-most bar) will be shown as usual but the right channel display will instead show the currently selected reference level.

This is achieved by lighting up a 12-LED section of the bar which moves up and down by one LED for each 1dB change in reference level. At the minimum setting of -20.0dBV, this bar will start at the bottom-most LED, so you can figure out the whole number of decibels by counting the number of LEDs before the bar starts. At the maximum setting of +7.4dBV, the bar will stop one LED from the top.

The fractional number of decibels is indicated by switching off one LED within the bar. If the number ends in .0, the second LED will be off. If it's .1, the third LED will be off, and so on until it's .9 in which case the second-from-last LED will be off. This may sound complicated but once you see it in action, you should find it pretty easy to figure out.

A quick press of S1 will reduce the selected reference level by 0.1dB while a quick press of S2 will increase it by the same amount. Because the left-channel bar operates normally, you can observe the effect of changing the reference level on the display, and adjust it for a particular level for a particular signal should you wish. Hold down S1 for at least half a second in order to set the level for the other channel. You can switch back and forth, adjusting the levels as required.

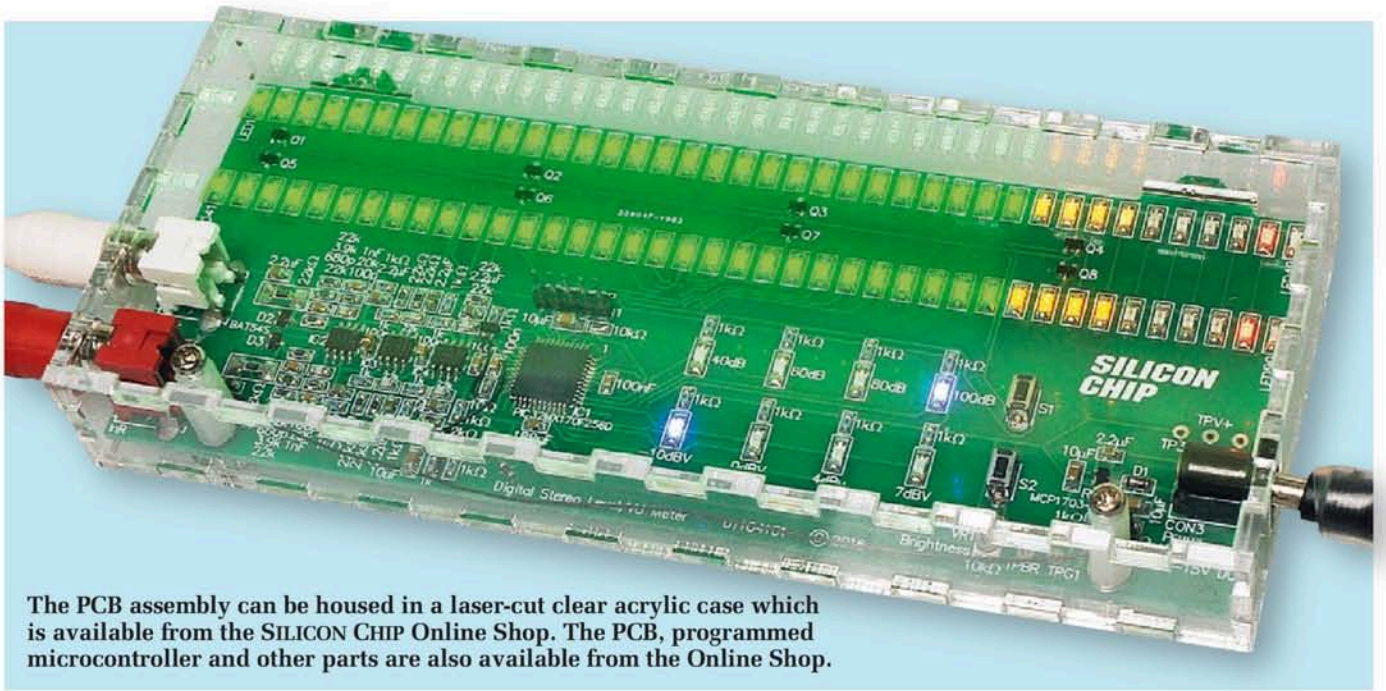
When you've finished, hold down S2 for at least half a second and the changes will be saved. The unit will return to its normal display. If you want to abort changing the reference level, simply pull power from the unit.

There's one extra function available in this mode: if you press S1 and S2 simultaneously (briefly), it will copy the level setting from the other channel to the currently selected channel. This makes it easy to set both channels to the same (or a similar) reference level.

Changing the averaging/ peak hold period

When the unit is in VU mode (modes 4 & 5 shown in Table 1), the unit performs RMS averaging on each block of 1024 samples and then uses a ballistic simulation of a moving needle to provide the required 300ms settling time to 99% and 1-1.5% overshoot for a VU meter. But in the other modes, the average value is calculated by averaging one or more of the RMS amplitude results from the 1024 sample blocks.

By changing the number of values averaged, you can change the response time. The minimum is one block, representing around 25ms of signal, and the maximum is 40 blocks, ie, around one second's worth of data. Similarly, the peak value is calculated as the maximum peak value of between one



The PCB assembly can be housed in a laser-cut clear acrylic case which is available from the SILICON CHIP Online Shop. The PCB, programmed microcontroller and other parts are also available from the Online Shop.

and 40 blocks worth of data. You can change both values. Changing the peak calculation period will also affect the VU-style mode if the peak is shown.

To adjust these settings, simply hold down S1 while applying power, then press S2 once. LED85 should flash and you can then release S1. The averaging window size is shown by which of LEDs1-40 is lit; LED1 indicates averaging over one sample block, LED2 over two, etc. Similarly, LEDs41-80 show the peak period.

Initially, one LED will be flashing in the top row. Press S1 to reduce the averaging window size by one sample block or S2 to increase it. Hold down S1 for at least half a second to switch to the other row, to adjust the peak calculation period, and use S1/S2 to reduce/increase it. When finished, hold down S2 to save the settings and return to normal operation. To abort the changes, simply pull power to the unit.

LED brightness adjustment

If you're using different colour LEDs which are reasonably well matched in terms of brightness, the display should look good without any further adjustment. However, if you're particularly fussy or using different LEDs which are not so well matched, you may find that some are noticeably brighter than others.

We have incorporated a feature to allow you to dim a subset of the LEDs in the display in order to match the brightness. There are a few limitations (explained below) but this method generally works quite well.

To access this setting, hold down S2 while powering the unit up, wait for at least half a second, then release it. Only LED1 and LED2 will be lit. They will be driven at maximum duty cycle, to allow you to compare the brightness of the two LEDs. Short presses of S1 and S2 change which pair of LEDs are lit, to the left and to the right respectively. Use these to light up the first pair of LEDs which have a significant difference in brightness.

You can then rotate VR1 to adjust their relative brightness until they appear to be matched. Use S1/S2 to move along until you find another pair of LEDs with mismatched brightness and adjust those too. Continue until you reach the final pair of LEDs for the left channel, LEDs39 & 40. At this point, pressing S2 will illuminate the entire top bargraph and the LED brightness will be adjusted based on the settings you have made so far.

You can now use VR1 to adjust the overall brightness of the bar. Note that if you have made more than one adjustment, because they are cumulative, you may find that the brightness matching is not perfect. You can now press S1 and make further adjustments before returning to the "preview" mode. Continue until you are satisfied with the result, then use S2 to switch to the bottom bargraph and use the same procedure to match the brightness of its LEDs.

Once you have selected a pair of LEDs and rotated VR1, the brightness offset for that pair remains adjusted. To clear this adjustment, select the pair of LEDs, then hold down S1 for at least half a second. They will be reset to their original state. Holding down S2 for at least half a second resets all LEDs to their default states and allows you to start the adjustment procedure from the beginning.

When you are satisfied with the result, press S1 and S2 together briefly and release them. The changes will be saved and the unit will return to its normal operating mode. Changes are stored in flash memory so the unit will apply them each time it is powered on.

To make further changes to the relative LED brightness you will need to remove power and repeat the procedure. To disable this feature, re-enter the adjustment mode and hold down S2, then save the changes.

Limitations

The limitations are as follows. Firstly, any relative brightness adjustment will reduce the overall maximum brightness of the display. Secondly, the software supports up to four different brightness levels within each bank of 10 LEDs. Making adjustments that would require more than this will have undefined consequences. Also, making relative adjustments that are too extreme may result in a flickering display.

Finally, the signal-to-noise ratio of the unit and its ability to register very

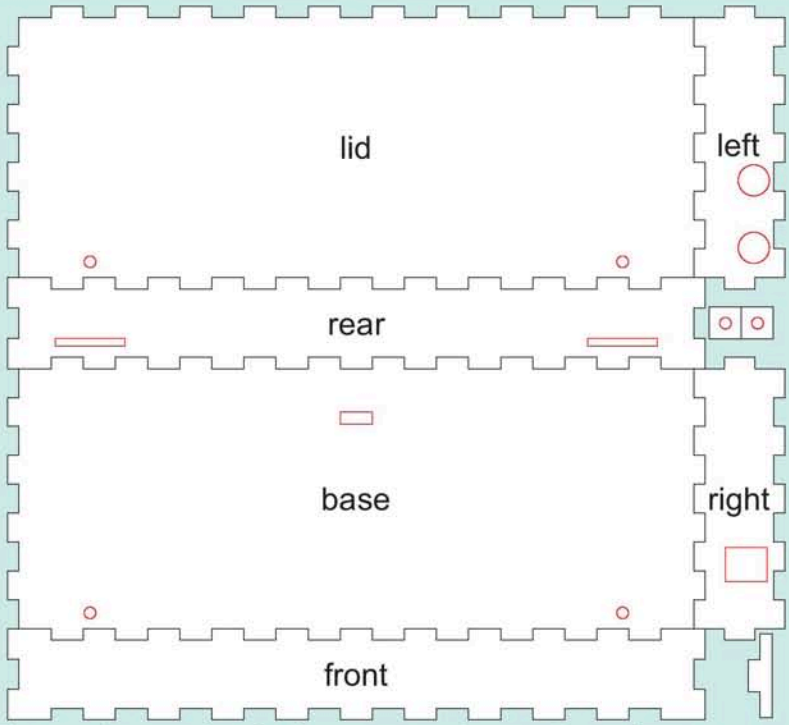


Fig.5: cutting template for the custom-made case. It's cut from a 208 x 190 x 3mm sheet of clear acrylic (polymethyl methacrylate, Perspex, Lucite, Plexiglas, etc). The red lines show the internal hole cut-outs. The three extra small pieces are used to space the board off the base, while the two slots in the top side allow the mounting tabs in the PCB to fit through (although they should normally be removed, see text).

brief signal peaks may be slightly impacted by this feature.

Laser-cut case

For those building the Level/VU Meter as a stand-alone unit, we have designed a clear acrylic case. It consists of six pieces that are glued and screwed together and is just a little bit larger than the PCB itself, giving a compact assembly. The cutting details are shown above in Fig.5 and one of the photographs shows the result.

All parts except for the lid should be glued using a specialised, solvent-type plastic adhesive. We used a tube of SciGrip "Weld On" 16 fast set clear, medium-bodied solvent cement. This is available from Plastix [Sydney (02) 9599 2499 or Northern Beaches (02) 9939 0555].

Note that the PCB has two trapezoidal tabs at the top with mounting holes. These tabs are not required if using the laser-cut case and can be cut off using a fine-bladed hacksaw or similar tool (the sides of the tabs are squared to make this task easier).

Note that you can still get the PCB into the case with the tabs intact (as shown in our photos) but it looks a little odd and makes it much more difficult to remove the PCB later if that should be necessary.

The first step in assembling the case is to attach the PCB to the base. You can identify this as it is the large piece with two round holes and one rectangular slot. A small T-shaped piece of plastic is supplied and this is glued into the rectangular slot after removing the protective film from both pieces. This small piece forms a support for the top part of the PCB.

Two small square pieces with holes in the middle are also supplied. Remove their protective film and place them over the holes in the base. Feed a 10mm machine screw up through each pair of holes.

You can then drop the PCB down on top, with the two screws passing through the mounting holes at the bottom of the board. That done, place a pair of 3mm ID shakeproof washers on each screw shaft and then screw an M3 x 12mm tapped Nylon spacer loosely onto each, holding the PCB in place. Make sure the square supports are orientated parallel to the edge of the board, then tighten the spacers up.

Now mock-assemble the case, with the protective film still on the remaining pieces, to ensure everything fits. You can temporarily fit the top panel to the two spacers using M3 x 6mm machine screws but don't do them up too tightly as they may prevent the sides from going on. Push the other four pieces into place and make sure everything fits. If it does, remove the top panel and take the protective coating off both sides, then screw it back on.

It's a good idea to keep a clean, disposable cloth on hand while gluing the case, to wipe off any excess glue quickly before it starts to set. Try to avoid getting the glue on any of the external faces of the case since it can cause hazing.

It's now basically just a matter of removing the protective film from the rear, front and lefthand (input side) pieces and gluing them in turn to the base panel and to each other. Coat all the mating surfaces with the solvent glue before pushing the panel into place and ensure it can't move until the glue hardens after 5-10 minutes. Full strength is achieved after 24 hours.

If you need to get the PCB out of the case, it will be necessary to slide it out, pulling the RCA socket barrels out of the holes in the lefthand side of the case. **To allow this, the righthand side piece should be glued not to the rest of the case but to the DC socket.** This will hold it in place but allow it to slide out with the board should you need to remove it (assuming you have cut off the top tabs). Like the rest of the pieces, its protective film should be removed before it's glued.

Other case options

The Level/VU Meter could also be fitted into a case with a clear lid, such as the Altronics H0332A Sealed ABS Enclosure (220 x 165 x 60mm), although this may be more expensive. It does have the advantage of being sealed against moisture and dust but you would have to use suitable sealed connectors for input and power to keep the IP65 rating for the finished unit.

In this case, you would simply need to fit tapped spacers to the four mounting holes on the PCB and either screw and seal or glue these to the base of the case.

Alternatively, the PCB assembly can be fitted into an amplifier chassis, behind a clear window on the front of the unit, and attached via those same four mounting holes. SC

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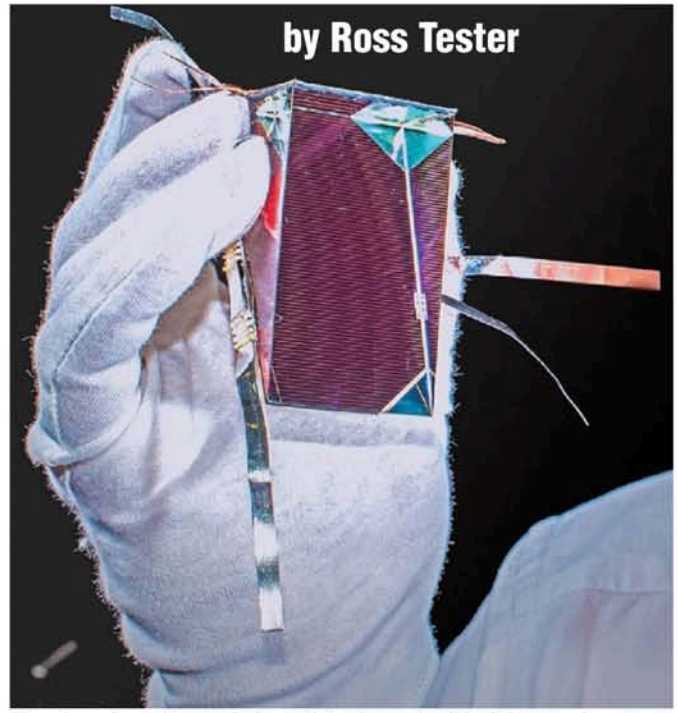
by Ross Tester



The four-junction mini module is embedded in a prism to split the incoming sunlight into four colour bands, which allow maximum efficiency in conversion to electricity.

Researchers at the University of New South Wales Australian Centre for Advanced Photovoltaics have pushed sunlight-to-electricity conversion efficiency of solar cells to 34.5% – establishing a new world record for unfocussed sunlight and nudging closer to the theoretical limits for such a device.

The record was set by Senior Research Fellow Dr Mark Keevers and ACAP Director, Professor Martin Green.

They used a 28cm^2 four-junction mini-module – embedded in a prism – that extracts the maximum energy from sunlight. It does this by splitting the incoming rays into four bands, using a hybrid four-junction receiver to extract even more electricity from each beam of sunlight.

The new UNSW result, confirmed by the U.S. National Renewable Energy Laboratory, is almost 44% better than the previous record of 24% efficiency, held by Alta Devices of the USA. That record was created over a larger surface area of 800cm^2.

"This encouraging result shows that there are still advances to come in photovoltaics research to make solar cells even more efficient," said Dr Keevers. "Extracting more energy from every beam of sunlight is critical to reducing the cost of electricity generated by solar cells as it lowers the investment needed, and delivers payback faster."

The result was obtained by the same UNSW team that set a world record in 2014, achieving an electricity conversion rate of over 40% by using mirrors to concentrate the light – a technique known as CPV (concentrator photovoltaics) – and then similarly splitting out various wavelengths. The new result, however, was achieved using normal sunlight with no concentrators.

"What's remarkable is that this level of efficiency had not been expected for many years," said Professor Green, a pioneer who has led the field for much of his 40 years at UNSW. "A recent study by Germany's Agora Energiewende think tank set an aggressive target of 35% efficiency by 2050

Dr Mark Keevers (left) and Professor Martin Green were responsible for the breakthrough and new world record, breaking the old mark by 45%.

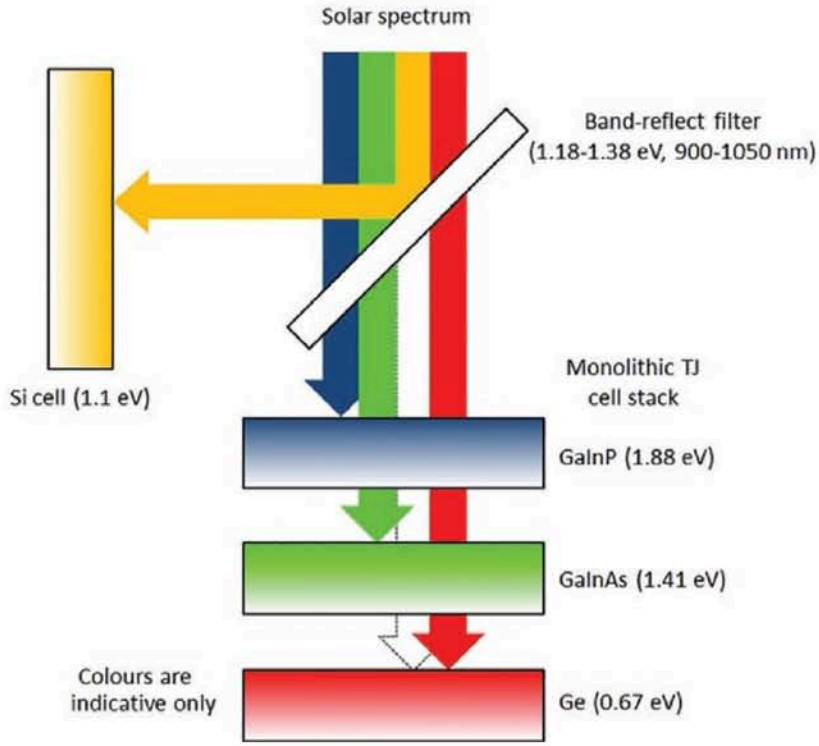
for a module that uses unconcentrated sunlight, such as the standard ones on family homes."

"So things are moving faster in solar cell efficiency than many experts expected, and that's good news for solar energy," he added. "But we must maintain the pace of photovoltaic research in Australia to ensure that we not only build on such tremendous results but continue to bring benefits back to Australia."

Australia's research in photovoltaics has already generated flow-on benefits of more than $8 billion to the country. Gains in efficiency alone, made possible by UNSW's PERC cells, are forecast to save $750 million in domestic electricity generation in the next decade. PERC cells were invented at UNSW and are now becoming the commercial standard globally.

The triple-junction cell targets discrete bands of the incoming sunlight, using a combination of three layers: indium-gallium-phosphide; indium-gallium-arsenide and germanium. As sunlight passes through each layer, energy is extracted by each junction at its most efficient wavelength, while the unused part of the light passes through to the next layer, and so on.

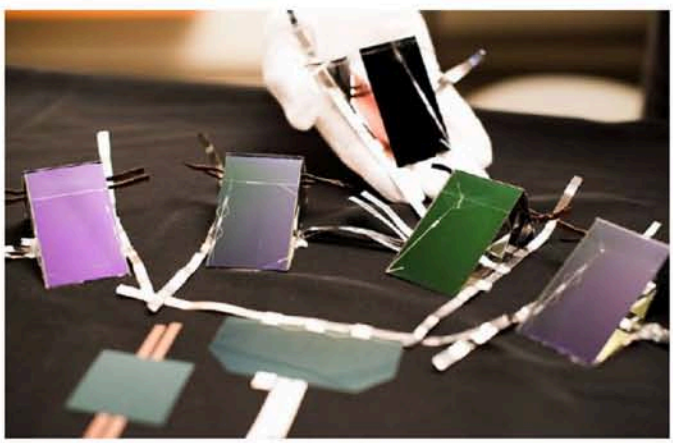
Some of the infrared band of incoming sunlight, unused by the triple-junction cell, is filtered out and bounced onto the silicon cell, thereby extracting a large proportion of the energy from each beam of sunlight hitting the mini-module.



Different photovoltaic compounds have a maximum efficiency at different wavelengths – hence splitting sunlight into various bands using a prism achieves a much better result than current cells, which use white light. Note that three of the four bands are in the infrared.

The 34.5% result with the 28cm^2 mini-module is already a world record, but scaling it up to a larger 800cm^2 – thereby leaping beyond Alta Devices' 24% – is well within reach. "There'll be some marginal loss from interconnection in the scale-up, but we are so far ahead that it's entirely feasible," Dr Keevers said. The theoretical limit for such a four-junction device is thought to be 53%, which puts the UNSW result two-thirds of the way there.

Multi-junction solar cells of this type are unlikely to find their way onto the rooftops of homes and offices soon, as they require more effort to manufacture and therefore cost more than standard crystalline silicon cells with a single junction. But the UNSW team is working on new techniques to reduce the manufacturing complexity, and create cheaper multi-junction cells.



Professor Green said that there is a long way to go from the working modules to commercial production – "perhaps as much as ten years" – but this is an enormous breakthrough.

However, the spectrum-splitting approach is perfect for solar towers, like those being developed by Australia's RayGen Resources, which use mirrors to concentrate sunlight which is then converted directly into electricity.

The research is supported by $1.4 million grant funding from the Australian Renewable Energy Agency (ARENA), whose CEO Ivor Frischknecht said the achievement demonstrated the importance of supporting early stage renewable energy technologies.

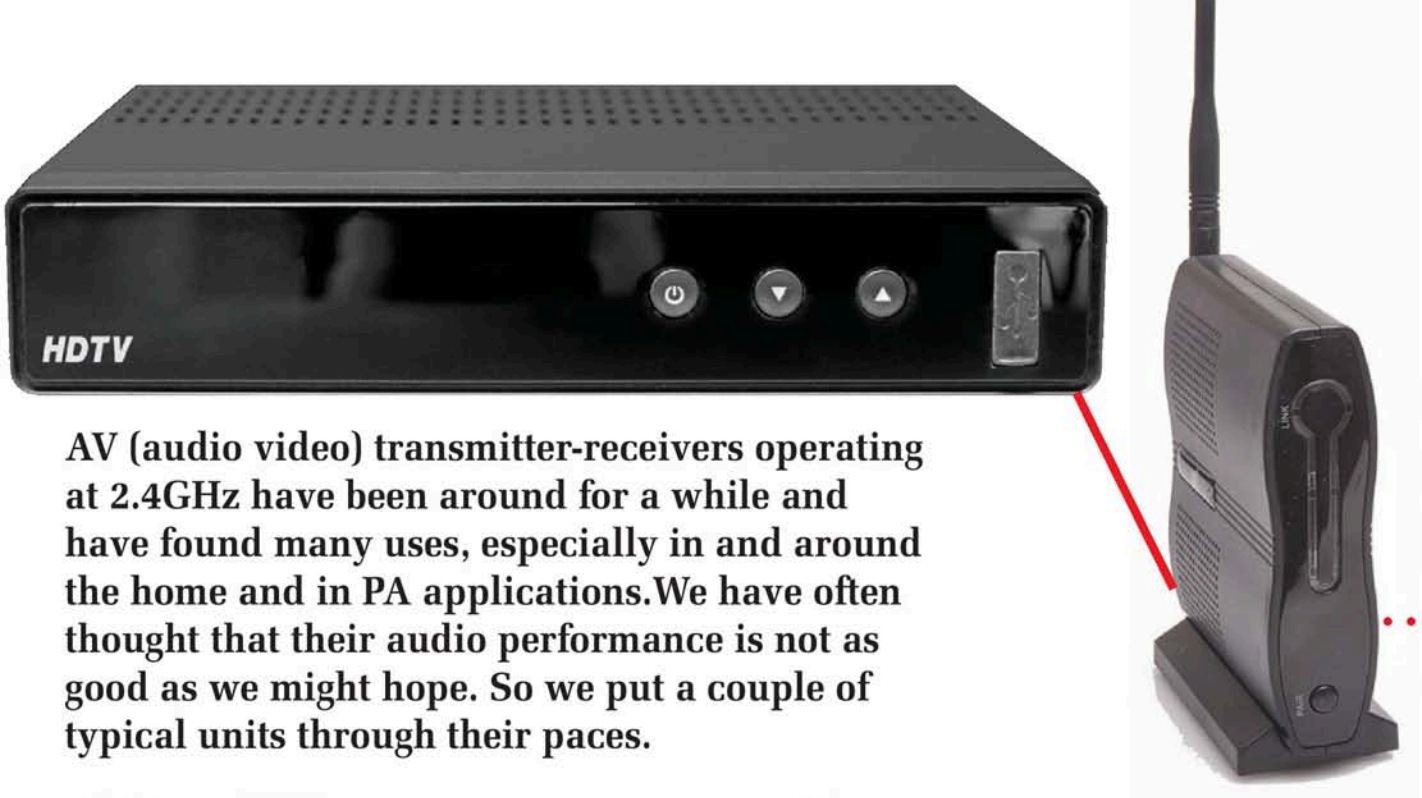
"Australia already punches above its weight in solar R&D and is recognised as a world leader in solar innovation," Frischknecht said. "These early stage foundations are increasingly making it possible for Australia to return solar dividends here at home and in export markets – and there's no reason to believe the same results can't be achieved with this record-breaking technology."

He noted that the UNSW team is working with another ARENA-supported company, RayGen, to explore how the advanced receiver could be rolled out at concentrated solar PV power plants.

"With the right support, Australia's world leading R&D is well placed to translate into efficiency wins for households through the ongoing roll out of rooftop solar and utility-scale solar projects such as those being advanced by ARENA through its current $100 million large-scale solar round, " he added.

"Over the longer term, these innovative technologies are also likely to take up less space on our rooftops and in our fields."

Other research partners working with UNSW include Trina Solar, a PV module manufacturer and the U.S. National Renewable Energy Laboratory. SC



AV (audio video) transmitter-receivers operating at 2.4GHz have been around for a while and have found many uses, especially in and around the home and in PA applications.We have often thought that their audio performance is not as good as we might hope. So we put a couple of typical units through their paces.

Q: How good are those A: JUST AWFUL!

By Allan Linton-Smith

We tested two different units, both of which operate at 2.4GHz. One came from Dick Smith Electronics (remember them?) – Cat A2288, which retailed for $179.

The other one was purchased on ebay for $50 (including shipping) and it is a generic model, #PAT220, from a Hong Kong supplier. Both units operate at a frequency of 2.4GHz although the DS model quotes 16QAM/QPSK/BPSK modulation modes to ensure security and interference-free operation.

The generic model operated at a fixed frequency but other frequencies were selectable via a DIP switch arrangement

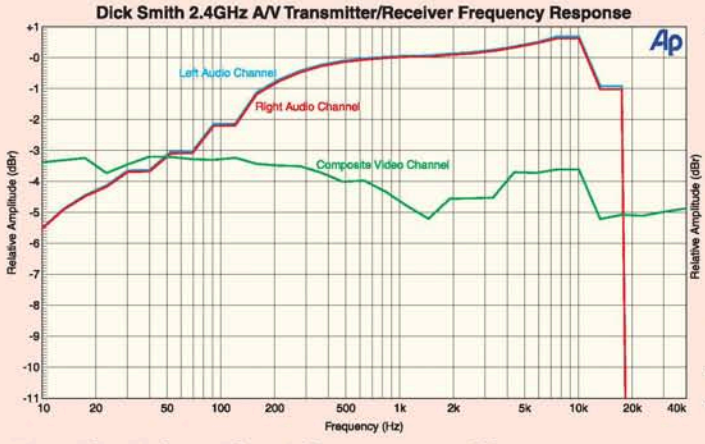


Fig.1: The Dick Smith unit has an unusual frequency response in the left and right channels and a somewhat flatter response for the mono AV input.

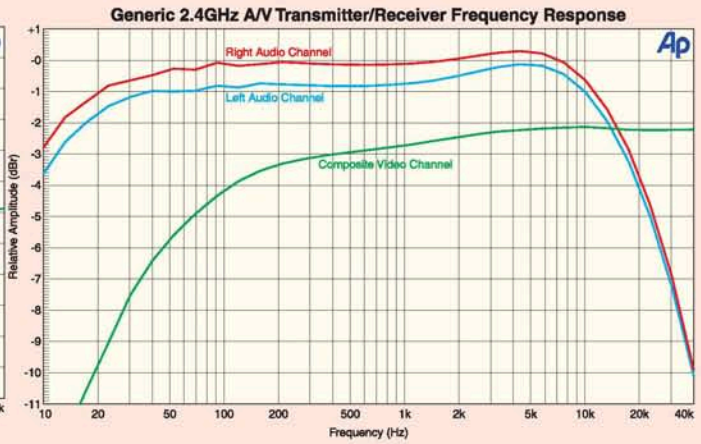


Fig.2: This is the frequency response of the generic 2.4GHz unit and smoother in all modes than the DS unit.

2.4GHz AV "Senders"?

to "tune out" any local interference or to adjust for the best picture and sound.

Both units were quoted as having a range of approximately 30 metres indoors and 100 metres outdoors and had a signal strength of around -23dBm at one metre.

Both units included an attachment to transmit IR signals for distant remote control to operation of devices such as TV, DVD etc.

According to the instruction booklet for the generic unit, the IR extender operates at 433.92MHz with a carrier frequency of 32kHz.

We assume that the DS model operates in a similar fashion but they do not specify any frequencies and we did not test the IR remote function of either unit, preferring to focus on the performance of the more important audio signals.

Frequency response

The response of the Dick Smith unit was quite flat, over the range from 200Hz to about 12kHz, and almost identical for the left and right audio channels, as shown in the cyan and magenta curves in Fig.1.

The response of the generic unit was better, with -3dB points at 12Hz and 17kHz, as shown in Fig.2.

There was a slight difference between left and right audio channels of around 0.5dB but this would undetectable in listening tests.

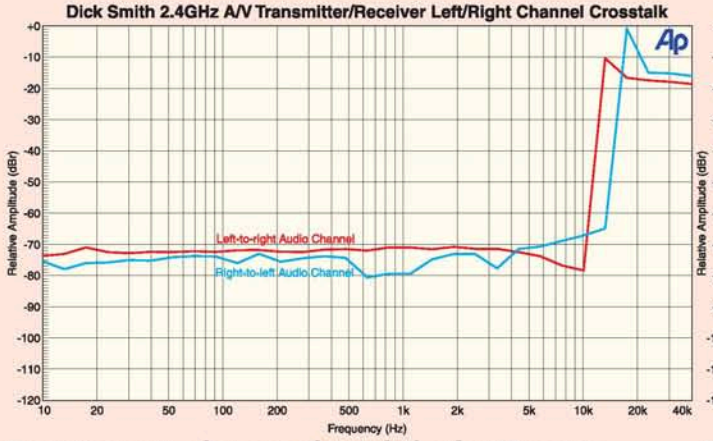


Fig.3: Separation between channels for the DS unit is satisfactory below 10kHz but is almost non-existent above that frequency.

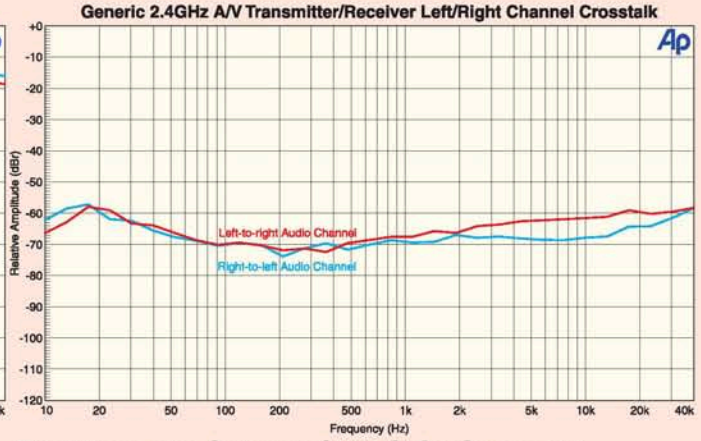


Fig.4: Separation between channels for the generic 2.4GHz unit is satisfactory over the full audio bandwidth.

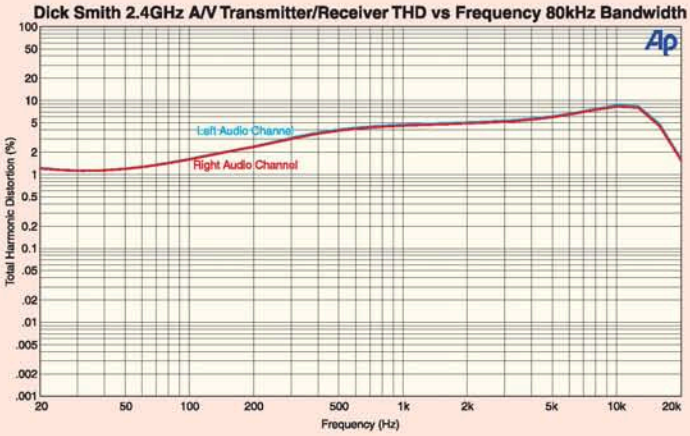


Fig.5: total harmonic distortion versus frequency for the DS 2.4GHz unit at 1V RMS. Note the rise to 9% at 10kHz and above.

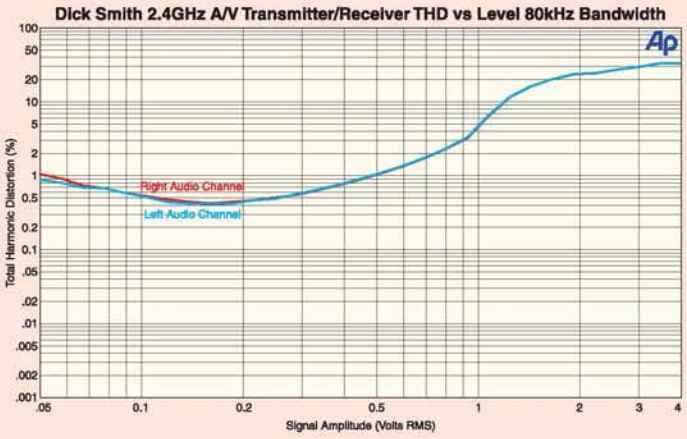


Fig.6: Total harmonic distortion versus signal level for the DS 2.4GHz unit at 1kHz. At 2V RMS it is above 20%; excruciatingly bad!

Separation between channels

The Dick Smith unit claimed good performance on this parameter, with separation of better than -70dB for both channels (ie, the effect of a LH signal on the right channel and vice versa), as shown in Fig.3.

But for frequencies above 10kHz, there was virtually no separation at all! That means that the resulting stereo "stage" will not be as wide and well-defined as you would get from a well-recorded CD.

On the other hand, as shown in Fig.4, the generic unit was significantly better right across the range and channel separation was more than -60dB from 10Hz to 40kHz; not that anyone can hear frequencies above 20kHz!

Harmonic distortion

Now we know that some of our readers think that we have an obsession with vanishingly low distortion levels (well OK, we do; see the Ultra-LD Mk4 amplifier) but even fairly average audio equipment should manage a harmonic distortion performance of better than 0.5% over the audio range at typical signal levels.

The Dick Smith unit did not even come close.

At an input signal level of 1V RMS (half the maximum signal level from a DVD or CD player) total harmonic distortion and noise (THD+N) was a whopping 5% at 1kHz and it climbed to 9% at 10-12kHz. See Fig.5.

These measurements seemed unusually high so all the test connections were double checked to ensure there were no hum loops. We also used three different Audio Precision analysers to confirm the measurements were correct and not created by any instrument problems.

It turned out that some of this distortion was created by good old-fashioned signal clipping, as can be seen from the waveforms in Scope1.

But even reducing the signal level does not bring about a major improvement; tests were also carried out on THD+N

The generic unit was bought on ebay for just $50.00 – including postage from Hong Kong!

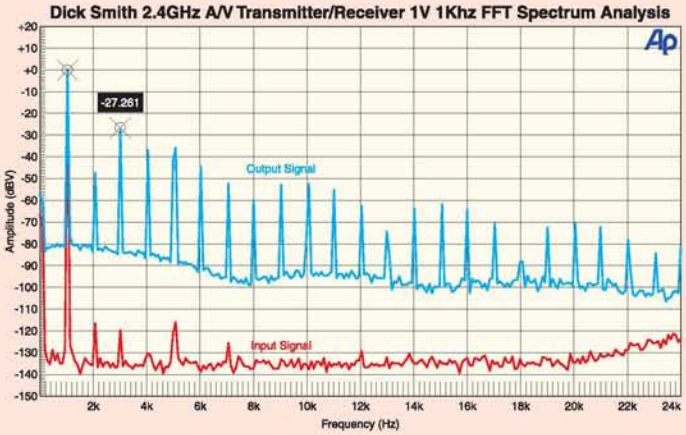


Fig.7: The FFT spectrum analysis for the THD measurement in Fig.5 reinforces the story: heaps of high level harmonics.

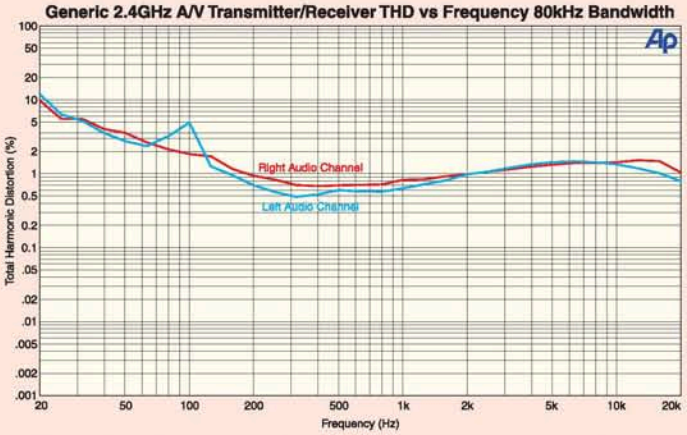


Fig.8: Total harmonic distortion versus frequency for the generic 2.4GHz unit at 1V RMS. Note the rise to 10% at 20Hz; not good.

versus input strength and somewhat better figures (less bad!) were obtained at input levels of less than 0.5V RMS but this would still not be considered "hi-fi". See Fig.6.

And have a look at the THD when signal level rises to 2V RMS – the distortion is well above 20% – that's due to severe clipping.

Note that there is no input level control on the Dick Smith 2.4GHz AV unit or any other generic unit that we know of, so if you plug in a typical DVD or CD player which has a maximum audio signal output level of 2V RMS, you will inevitably get bad distortion. It cannot be avoided unless you can reduce the signal level. That's hard to believe but true.

Furthermore, if you look at the FFT analysis for the DS unit it shows a virtual forest of harmonics!

In fact the third harmonic of 3kHz is only 27dB lower than the fundamental signal of 1KHz! See Fig.7.

Results on the generic unit were actually worse; extremely high in the bass frequencies with a whopping 10% at 20Hz. See Fig.8.

Fig.9 shows that performance is slightly improved at input levels of less than 1V RMS but increases significantly at levels lower than 200mV RMS. And have a look at the THD as the level goes above 1V RMS; it is almost the same as the DS unit; awful,

The FFT analysis of the generic unit was better than the Dick Smith unit with a third harmonic 42 dB below the fundamental. See Fig.10. Overall, the distortion performance of both units was just poor.

Transmitted bandwidth

The OBW (occupied bandwidth) of the Dick Smith unit was 78.8MHz at a CF(centre frequency) of 2.4425GHz which is exactly within the manufacturer's specification. The generic unit was factory set at 2.3726GHz but other settings could be made via the DIP switches up to 2.4537GHz; these had to be set on both the transmitter and receiver. Hence, the total usable bandwidth was around the same at 81MHz.

Subjective testing

Both units were tested on a Samsung 80cm TV set with normal speakers using a variety of program material. The transmitter was placed 10m from the receiver but was not in direct line of sight.

The DS unit paired in well, with the picture held solidly and there was absolutely no interference.

The sound was steady with no pops or crackles but that is the good news.

Otherwise, the sound quality can only be described as poor, with very noticeable distortion at the higher frequencies. Percussion instruments, for example, came across with a typical "crashing wave" distorted noise effect. This may not be a problem for normal domestic TV programs but it would definitely be unpleasant if you like to listen to music through a good quality amplifier and speakers or at high sound pressure levels. PA, guitar etc.

The picture quality can best be described as average – there was a distinct degradation of picture quality (pixelation) which was very noticeable when the TV was switched between direct input and transmitted input – so much so that some subtitles were barely readable.

The Dick Smith unit operates in the same 2.4GHz band. It also includes a set of 3-way A/V cables and an infrared receiver (not shown here).

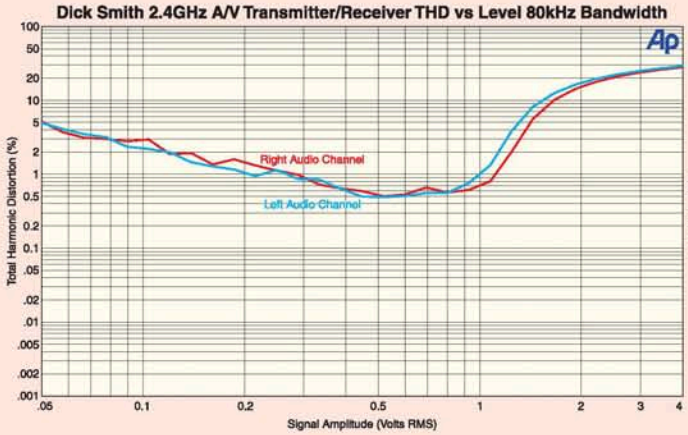


Fig.9: Total harmonic distortion versus signal level for the generic 2.4GHz unit at 1kHz. At 2V RMS it is approaching 20%; also excruciatingly bad!

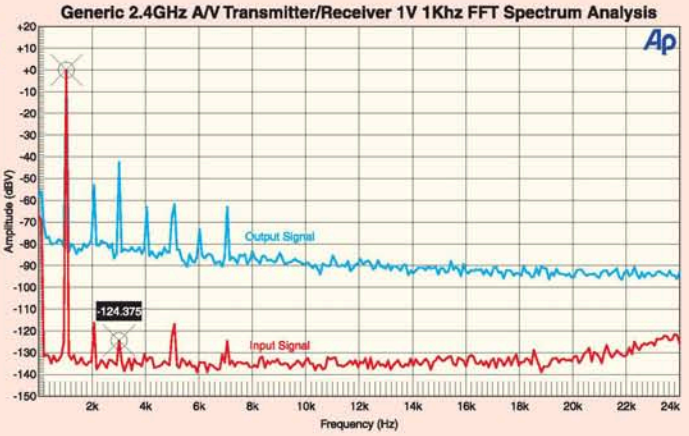


Fig.10: The FFT spectrum analysis for the THD measurement in Fig.9 reinforces the story: not as bad as the DS unit but still awful.

By contrast, the generic unit was significantly better in the picture department with no hint of pixelation and all subtitles were clear and readable.

The sound was not too bad either and you would have to listen carefully for distortion when the sound was switched between direct and transmitted. We did not use large speakers but we would expect distorted bass notes below 50Hz.

But rather unfortunately, the generic unit suffered terribly from both interference and pops and crackles from other household modem and WiFi devices, phones etc.

This was hard, if not impossible to tune out using the DIP switches and required some patience because, just when everything seemed interference free, an unexpected crackling signal would pop up .

Also the signal was interrupted altogether when a large person (me) stood in the signal path.

This would prove really annoying if you were watching a long movie or sports event.

In summary, despite the generally poor audio tests, these devices may be quite satisfactory in non-critical applications.

If you want a quick, easy remote AV set-up that doesn't require high fidelity, they can work quite well.

If you need to transmit TV to your bedrooms or CCTV security to remote locations or for "ordinary" PA, you will enjoy the versatility of these units.

But if you like listening to music and are using a high quality signal source, a high quality amplifier and speakers, or if you require them for PA quality music – you will be disappointed at the high distortion and poor frequency response from the transmitted signals.

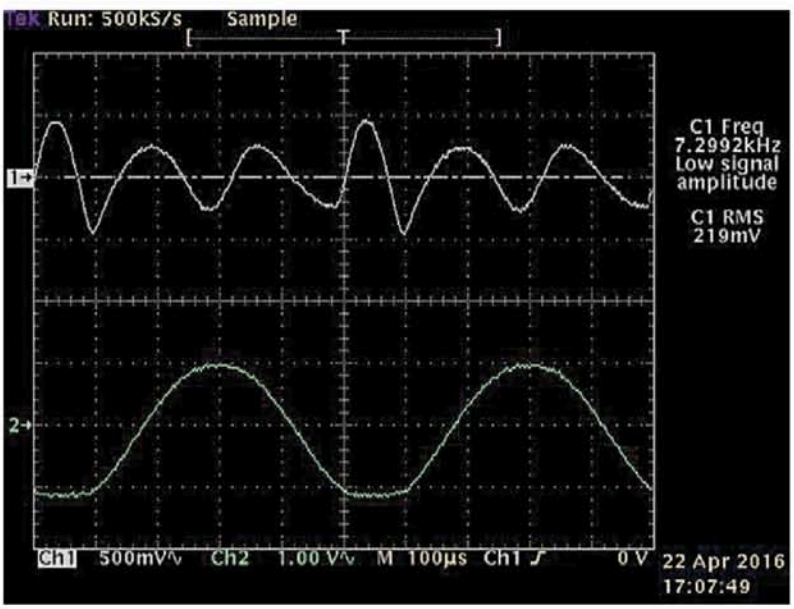
Hard-wired extensions such as low resistance speaker wire or balanced line cable or twisted cable arrangements for hi-fi or PA would be a better way to go for long distances.

Don't forget that the ID security coded signals from the DS unit (but not the generic unit) will prevent anyone else from tuning in and this would be recommended for CCTV security systems but not really necessary for movies or TV programs.

With the single frequency generic unit, several receivers can be tuned to one transmitter and this would be handy for PA at sporting events where it would be cheap and easy to set up several powered speakers.

Another advantage of the DIP switches is that they allow the user to "tune" in to various PA zones such as a dressing room or a marshalling area

The RF interference which was obvious in the cheaper generic unit could possibly be corrected with a fair bit of fiddling and setting the transmitters and receivers above head height to avoid signal loss.



Scope1: this scope grab shows the clipped signal at 1V RMS and the resultant residual distortion waveform after the 1kHz fundamental has been removed. A clipped signal will never sound good!

The price of these 2.4GHz AV links are coming down all the time but we would generally caution against using them for music and video if you require high quality sound and vision.

Of course, we have only tested two of these units. Others on the market might have much better performance. But unless the vendors make specific claims, you can probably assume that their performance is pretty mediocre. SC

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07/16

Vintage Radio

By Dr Hugo Holden

The Grebe Synchrophase MU-1 5-Valve Radio

If ever there was a radio that looked like it escaped from the laboratory where H. G. Wells' Time Machine might have been built, the Grebe MU-1 is it. Emanating from the electronics industry in New York in the mid-1920s, it really is an astonishing masterpiece of construction.

Grebe struck a combination of form and function with the MU-1 which, by any standards past or present, was extraordinary. At that point in history, 10 years was a very long time in the electronics industry and many radio companies made their fortunes during that era and then folded. Those that survived then faced the Great Depression of the 1930s.

Alfred. H. Grebe

Alfred H. Grebe (1895-1935) was by all accounts a child prodigy who showed an interest in electrical engineering and radio technology from a very young age. His first factory started out as a tool-shed in Richmond Hill, a borough of Queens in New York. His initial products were items such as simple crystal detectors.

During WW1, Grebe supplied radio apparatus to US Navy vessels and to the Allies. By 1922, the old factory had been torn down and a new, well-equipped facility built which housed two radio stations, WAHG and WBOQ.

The Synchrophase MU-1 radio became available around August 1924. An improved model, designated the MU-2, was subsequently released and this was produced until 1927. It is estimated that over 150,000 MU-1 & MU-2 radios were built over that time.

Grebe manufactured their own tuning capacitors, including an SLF (straight line frequency) type for the MU-1. This type of tuning capacitor used specially-shaped vanes to give a linear tuning response across the 0-100 dial scale. They also made rheostats to control the tube filament current and another type of switched variable resistor called a "color-tone" control. In addition, Grebe designed and built the radio's characteristic "binocular coils".

The Grebe's tuning system is unusual. It has three vertical tuning capacitor shafts fitted with edge controls. The three tuning capacitors are ganged together with a chain drive. This assists tracking and this allows easy tuning and station finding. There is enough chain slack to allow a small mount of fine adjustment.

Unfortunately, the Grebe Company went bankrupt during the 1931 to 1932 period, which was typical of the fate of many companies during the Depression. The company's founder, Alfred Grebe, subsequently died in 1935 at the relatively young age of 40 due to complications from bowel surgery.

Stability and neutralisation

Fig.1 shows the circuit details of the Grebe MU-1. The radio is a TRF type with two RF (radio frequency) stages (V1 & V2), a grid-leak detector stage (V3) and two stages of transformer-coupled audio amplification (V4 & V5), based on the standard 01A or 201A valve types. The RF stages are both neutralised, for stability.

Looking into a triode's grid drive circuit, the input capacitance (Ci) is the combination of the grid-cathode capacitance (Cgk) and the grid-plate capacitance (Cgp). However, the latter is amplified by a factor close to the amplification of the tube (μ) and so the input capacitance becomes:

$$Ci = Cgk + (1+ \mu)Cgp$$

Basically, the grid-to-plate capacitance value is amplified by the valve's gain. For purely resistive input (grid) and output (plate) loading, this feedback capacitance results in negative

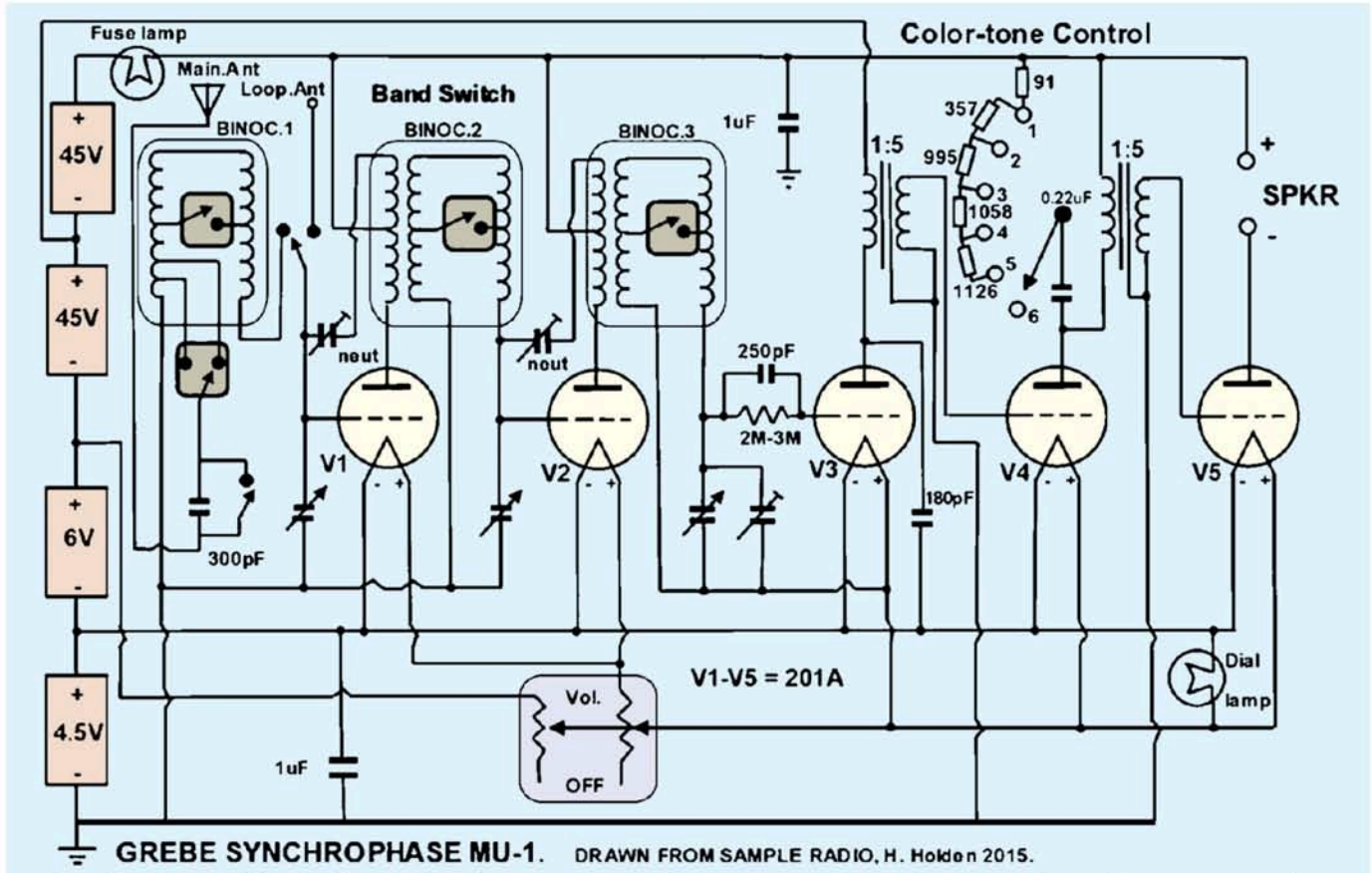


Fig.1: the circuit of the Grebe Synchrophase MU-1. It's a battery-powered, 5-valve TRF radio with two RF stages (V1 & V2), a grid-leak detector stage (V3) and a 2-stage transformer-coupled audio amplifier (V4 & V5). The valves are all 01A or 201A type triodes and the set covers two switched bands: 545-1250kHz and 833kHz-2MHz.

(degenerative) feedback because the signals at the grid and plate circuits are 180° out of phase. This rolls off (or lowers) the high-frequency response because the impedance of the feedback capacitance decreases with increasing frequency, shunting more of the drive signal.

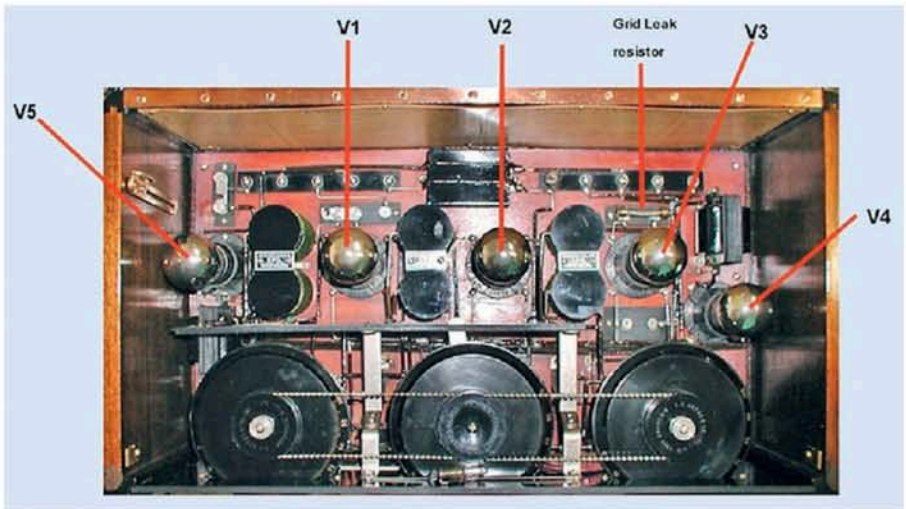
However, when tuned circuits are connected to the grid and plate, they can exchange energy with each other via the feedback capacitance. This feedback can become positive (or regenerative) and so the amplifying stage can become unstable and oscillate. To counter this, "neutralisation" is always required when a triode tube has tuned circuits with similar resonant frequencies in both its plate and grid circuits.

Conversely, no neutralisation is needed if the resonant frequencies of the grid and plate tuned circuits are far enough apart.

In the MU-1, neutralisation of V1 and V2 is achieved by an additional winding on the coil in each plate circuit which feeds back a signal to the grid via a small neutralising capacitor, called a "neutrodon" during the 1920s era. Basically, the signal fed back via the neutrodon to the grid phase-cancels the signal across the grid-plate capacitance (Cgp).

As technology progressed, the screen-grid valve was eventually developed, the screen shielding the plate from the grid circuit. This meant that neutralisation in RF & IF amplifiers based on tetrodes and pentodes was no longer required. However, neutralisation remains a common technique in triode-based RF amplifiers.

Neutralisation was also used in early transistors radios from about 1955-1965. This was necessary because germanium transistors such as the OC45



The three variable capacitors inside the Grebe MU-1 are linked together by a chain, so that they track together when stations are being tuned.

The MU-1's resonant or "tank" circuit is wound with green Litz wire and is divided across two separate coil formers. These are placed side-by-side so that any signals directly picked up by the coils are cancelled out.

were used in 455kHz IF amplifiers and these have a high collector-to-base capacitance, analogous to anode-grid capacitance in a triode.

As with valve circuits, neutralisation also eventually disappeared from transistor radios. Newer transistors such as the OC171 and AF125 (and the later silicon transistors) had very low collector-base capacitances, so neutralisation was no longer necessary.

If a triode valve is deactivated by turning off its filament current, the capacitance amplifying effect is eliminated and the value of Cgp can be accurately cancelled by adjusting the neutralising capacitor. This was the method commonly employed to adjust the neutrodon. It's interesting that this adjustment technique has no counterpart in the world of semiconductors as their gain cannot be deactivated with their collector-base feedback capacitance remaining.

That's because their feedback capacitance is affected by the collector-base voltage, much as it is in a varicap diode. It's simply not possible to deactivate the transistor's gain without altering its DC conditions.

The neutralisation circuit, or the "Neutrodyne" as it was called, was originally designed by Louis Hazeltine and was licensed in the 1920s era by a group of more than 20 companies that were members of IRM (Independent Radio Manufacturers). Grebe was not a member of IRM and was subsequently sued in 1927 but by then most of the MU-1 radios were obsolete. Grebe lost the case and had to obtain a Neutrodyne licence.

At least Grebe did not have to worry about Armstrong's regeneration patent, as it is not used in the MU-1.

Tuning frequency range

The Grebe MU-1 (except for some early production models) has two switched tuning ranges: 545-1250kHz and 833kHz-2MHz. The latter range is achieved using a sliding band switch which shorts out some turns on the binocular tuning coils. However, due to the binocular design of the coils (see below), this doesn't alter their Q to any great extent.

The band switching occurs automatically at either the 0 or 100 setting of the main central tuning dial. It's arranged so that the tuning mechanism pushes the slide switch one way or the other when the central tuning knob passes the end of its range. It can also be switched manually if one opens the radio's lid.

Binocular coils

The MU-1's resonant or "tank" circuit is wound with very attractive green Litz wire and is divided across two separate coil formers, hence the "binocular" appearance. Grebe checked the RF impedance during manufacture to ensure that every strand of the Litz wire had been soldered.

The two coils are placed beside each other and because the windings run in opposite directions, this reduces their mutual coupling. Any signals (eg, from radio stations or due to interference) radiated directly into this coil arrangement induces out of phase signals in the two coil halves and so the phases cancel. There's also limited signal pick-up from radio stations because of the vertical orientation of the coils.

The result was similar to that achieved with coil shielding but with no actual metal shield which always has the effect of lowering the circuit's Q.

Audio system

The detected audio at the anode of grid leak detector stage V3 is transformer-coupled into the grid of audio driver stage V4. This stage is then transformer-coupled to the audio output valve V5.

One notable feature is that V4 has a tone control circuit consisting of a "color-tone" switched variable resistance (based on insulated nichrome wire) and a series 0.22µF capacitor. It's interesting that they made the radio's tone control label analogous to a visual experience like colour. However, it's really not much different than some of the other analogies commonly used, such as "warm" sound or "bright" sound. So I do like the way they labelled this control.

When I received the radio, I noticed during the restoration process that the "color-tone" switched resistor was open circuit due to corroded nichrome wire.

It appears that insulated nichrome resistance wire was, and still is, available in various gauges from wire specialty companies in North America. By contrast, the British & Europeans preferred "Constantan" or "Isotan" wire and this is also still available, either bare or insulated.

Constantan wire is a mixture of copper and nickel and its resistance has a nearly zero temperature coefficient over a wide range. Not only that, it is extremely easy to solder (unlike nichrome), doesn't have the annoying springy quality of nichrome wire and is corrosion resistant.

In my case, I was able to rewind the color-tone control using about 43 metres of 36 AWG insulated nichrome wire which I tracked down in the USA. However, I could have equally well

used insulated Constantan wire which is more readily available on eBay.

Volume control

The volume control in the MU-1 consists of a dual-gang rheostat which controls the filament current to all five valves. Power for the filaments is provided by a 6V lead-acid accumulator designated the "A" battery. The other batteries are two 45V types connected in series and together these make up the "B" battery which supplies the HT. This "B" battery supplies 90V to the plate circuits of V1, V2, V4 & V5, while detector stage V3 is supplied with 45V HT (the detector stage will also run from 22.5V if required).

In addition, a 4.5V "C" battery is used to negatively bias the grid circuits of V4 and V5 so that these valves are correctly biased for class-A operation. The loudspeaker is a high-impedance type and is placed directly in the anode circuit of V5 without a matching transformer. Grebe recommended the use of a paper-cone speaker rather than a metal diaphragm horn speaker to improve fidelity.

The two interstage audio transformers appear to be identical in my radio but some models have transformers with different sizes. Grebe made their transformers "in house", including the lamination stampings. They have a primary DC resistance of around 350Ω and a secondary resistance of around 6kΩ. The turns ratio is around 1:4.9, while their impedance ratio is about 1:24.

Grebe filter capacitors

Grebe fitted two box-shaped "non-electrolytic" filter capacitors to the MU-1, one across the 90V B+ rail and the other across the C+ rail. These two capacitors were enclosed in a single case and had a measured value of around 1µF in my radio, although values of 1.5µF were reportedly used in other radios.

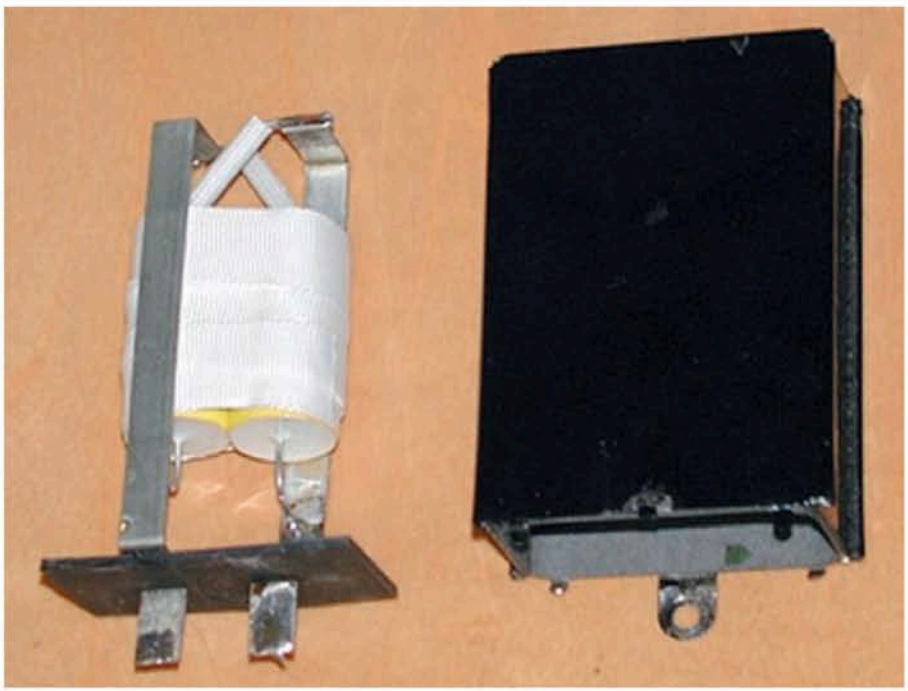
Both capacitors in my radio had a high leakage current, so the case was opened and two high-quality 1µF 630V polyester capacitors substituted. These capacitors were simply soldered to the metal strip contacts and held together with fibreglass tape for mechanical stability.

Fuse bulb

Instead of using a traditional fuse, Grebe fitted a 1.5V torch bulb in series with the 90V B+ supply to act as a fuse in the event of a filament-to-plate short circuit in one of the valves. Apparently, this could happen if the cabinet's lid was slammed shut or drop-closed, rather than gently lowered into position. This light bulb "fuse" helped to protect the transformers and coils in the radio from being burnt out by the B+ supply if a short-circuit did occur.

Many Grebe radios also included a 6V dial lamp. This was powered from the filament supply and lit the central knob scale via a small gap between the escutcheon & knob.

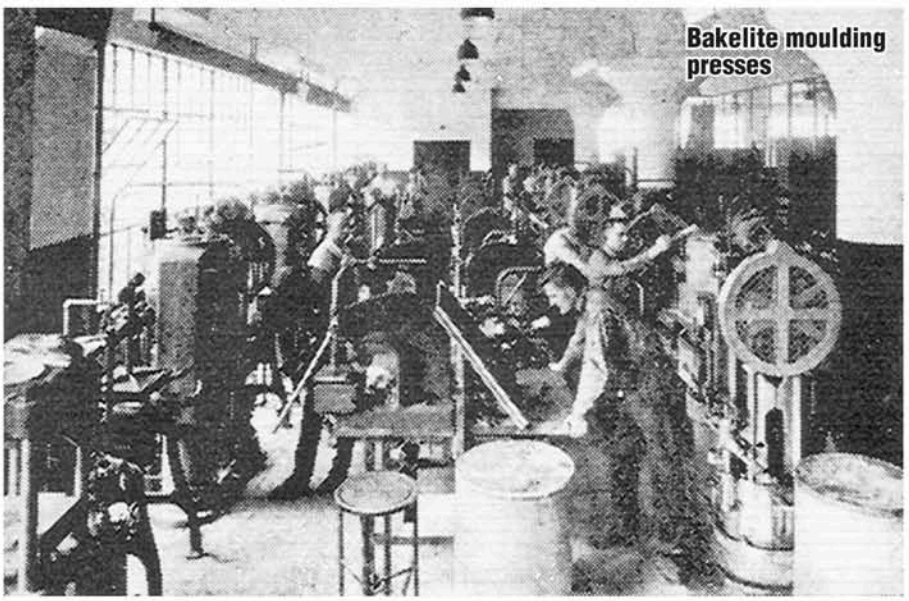
A card attached to the inside rear panel of MU-1's cabinet details the receiver's features, while a second card shows the battery and speaker connections.

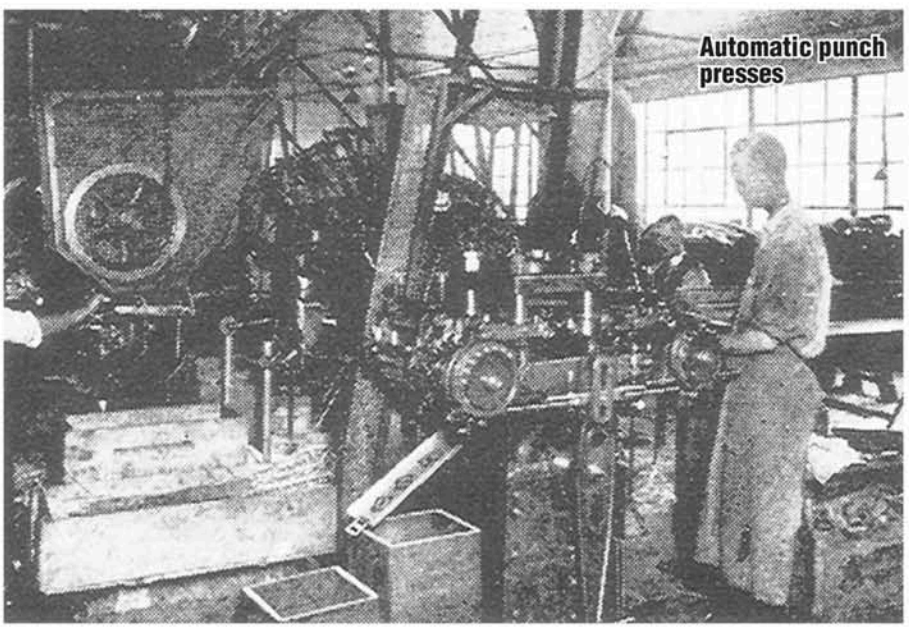


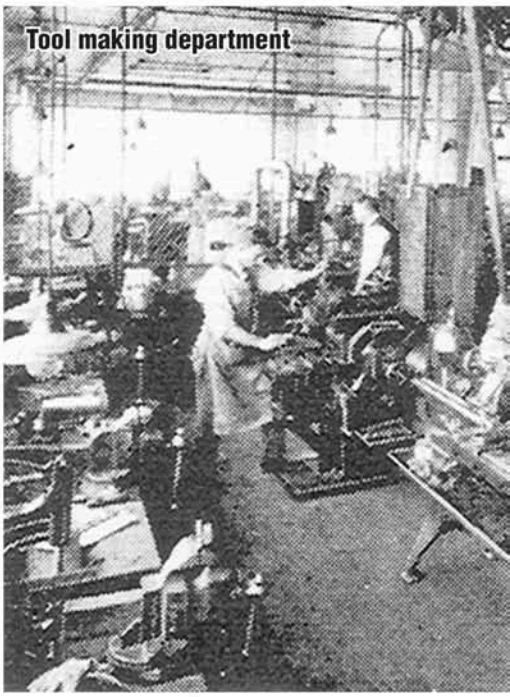
The two 1µF bypass capacitors used in the circuit are housed in a box-like case. This photo shows the two replacement capacitors wired in position across the internal metal strips.

Physical construction

The MU-1's cabinet is made of solid mahogany, while the front panel is made from polished Bakelite with a deep red, patterned appearance. The escutcheons around the edge knobs







Left & above: this group of photos shows various sections of the Grebe Company's factory during the 1920s. Grebe manufactured most of the parts for their radios, including tuning capacitors, coils, rheostats and even Bakelite valve sockets. The company ceased operation during the Great Depression.

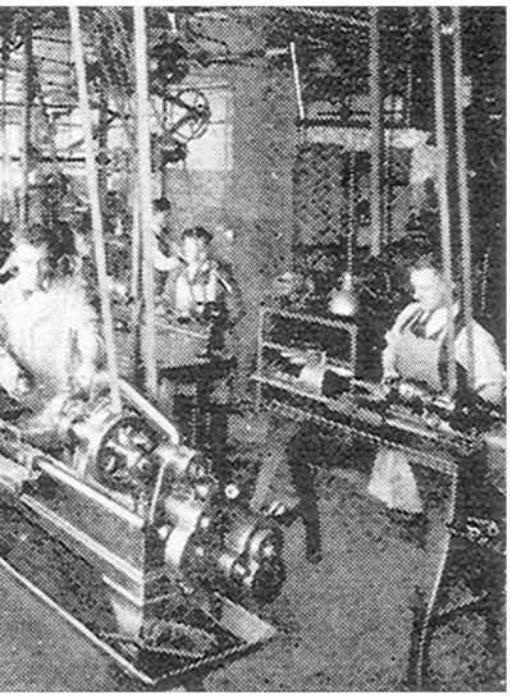
are pressed from brass and were gold-plated and clear-lacquered. These had darkened to black on my unit when I first received it. However, I found I could restore them to a gold-like finish by lightly polishing them and applying a protective lacquer.

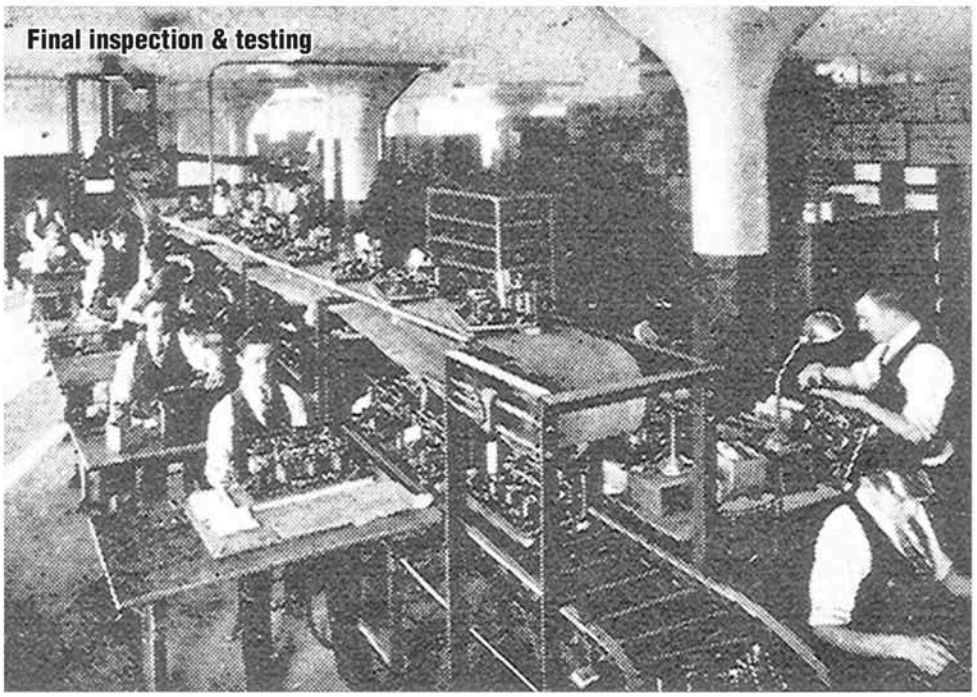
The cabinet finish on my radio was also was very poor and so it was stripped and refinished to make it look new again. As shown in one of the photos, a card attached to the inside of the cabinet details the receiver's features, while a second card shows the battery and speaker connections.

It's interesting to note that Grebe even made the Bakelite valve sockets fitted to the MU-1 and these used special "springy" pins to help minimise microphonics. It appears that two different socket variations were used over the years.

Cryptic serial numbers

Each Grebe MU-1 has a cryptic serial number system which has thus far stumped collectors. It consists of four letters on the instruction card inside and also engraved into the inside front panel and filled with white paint.





Final inspection & testing

Grebe must have had a secret method to decode the manufacturing date or other features from these letters. To date, none of the letter combinations has been found to correlate with the various changes that Grebe made from 1925-1927. If you feel inspired to crack this case, search the net on this topic and buy a copy of "The Code Book". Perhaps the Germans should have had Grebe build their Enigma Machine!

Neutralising the MU-1

It's quite easy to neutralise a Neutrodyne receiver such as the Grebe MU-1.

The first step is to set the volume control mid-way and couple a strong 1kHz (or thereabout) modulated mid-band signal to the antenna. The radio is then tuned to this signal and the generator level adjusted to give a moderately loud audio output.

The first RF valve (V1 in this case) is then removed from its socket and the radio re-tuned for maximum audio output (the audio will now be quite faint). A small amount of paper is then wrapped around one of V1's filament pins to insulate it and V1 reinstalled (ie, V1's filament circuit is disabled).

Using a low-capacitance insulated tool, the small neutralising capacitor associated with V1 is then adjusted to give minimum signal output. And that's all there is to it – the stage is now neutralised and V1 can now be removed and refitted to its socket without the insulating paper.

The same process is repeated to neutralise the stage based on V2.

Grebe's marketing strategies

Because of their high quality, one might think that Grebe radios would have sold themselves and that marketing gimmicks would not have been required. However, Grebe created a fictitious Chinese doctor named "Dr Mu". This referred to the symbol "μ" which is the amplification factor of a valve and, in fact, the "μ" symbol is seen on his hat.

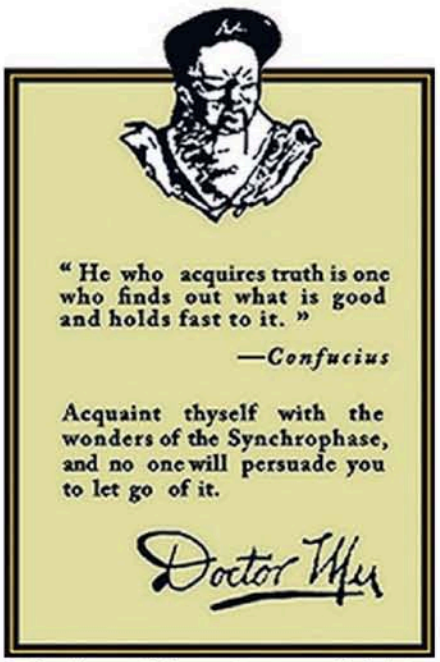
Dr Mu would quote Chinese philosophers and link their wisdom with the quality and value of Grebe radios. Grebe used Dr Mu from the early 1920s to help market all their radio models.

Low audio output

The Grebe radio, like many radios from the 1920s, uses a single 201A valve as the audio output device. This means that its maximum audio output without significant distortion is only about 20mW, depending on the speaker impedance and battery voltage.

One reason for its low output relates to the 201A's high plate resistance. This is around 11kΩ and is a poor match with the speaker impedances commonly used which were invariably much lower values.

By contrast, the UX112A valve, which is basically a higher power version of the 201A, has half the 201A's plate resistance and is capable of delivering 30mW with a 90V supply, or about 115mW with a 135V supply and an appropriately matched load.



A fictitious Chinese doctor called "Dr Mu" was part of Grebe's marketing strategy for the MU-1 Synchrophase.

It's difficult to imagine how Grebe could have improved the MU-1. The physical build of this radio is outstanding, the appearance delightful and the performance nearly as good as a superhet. In my opinion, it has certainly claimed its place in radio history and makes a great addition to any vintage radio collection. SC

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Got a technical problem? Can't understand a piece of jargon or some technical principle? Drop us a line and we'll answer your question. Send your email to silicon@siliconchip.com.au

Using Multi-Spark CDI with a twin output coil

I have a question regarding your Capacitor Discharge Ignition system from the December 2014 & January 2015 issues. Would this be capable of firing a twin output CDI coil or would the capacitor values need adjusting? When I refer to a twin output coil, I mean one which provides two sparks at the same instant, such as on a Suzuki X7.

I want to fire a single cylinder 4-stroke motor which has two sparkplugs in the cylinder head. I am assuming connecting such a twin output coil to your design will result in two sparks, each having only 50% of the energy that a single spark would possess. (Neil, Ireland, UK.)

● The coil energy would be divided between the two high-tension spark plug outputs and so you could use another 1µF X2 class capacitor in parallel with the existing Multi Spark Capacitor Discharge Ignition's capacitor to improve spark energy in each sparkplug. Alternatively, use a single 2.2µF X2 class capacitor instead of 1µF.

Precision driver for a Japanese turntable

I would be very interested in this project but I'm not sure if it's suitable for use with my turntable. It is an old but very good Japanese belt-drive turntable labelled 100VAC 50/60Hz so it doesn't quite fit in either of your mains supply options.

I currently use a small step-down transformer from 230VAC to 100VAC to power it and its accompanying vacuum pump and as it indicates 50/60Hz I don't think I have any pitch problems. I have no intention of travelling with the turntable which is too big and heavy for that anyway.

Would I need to change the Turntable Driver circuit for it to work with my unit? (B. H., Stirling, ACT.)

● It seems likely that your turntable is in fact a direct-drive model with no need for a precision 50Hz (or 60Hz) supply. Hence, there is no point in building the project. However, it may be worthwhile to build the Turntable Strobe from the December 2015 issue so that you can check how closely the turntable runs to the correct speed.

Re-purposing a solar battery charger

In the days of *Electronics Australia*, I built their Intelligent Solar Battery Charger by Peter Phillips and Conrad Marder. It has been in almost constant use since, commencing work on my boat using a solar panel and over the last 15 years, controlling an old Pye model charger.

I now have a small caravan which does not get much use; it is equipped with solar panels and a 240VAC switchmode charger which failed after five years, leaving the van batteries flat and six electrolytic capacitors popping their tops.

My question is: can I install a suitably-sized transformer and bridge rectifier and direct the rectified output through the existing solar regulator,

Stereo Audio Switcher Not Suitable For Switching Speakers

In the January 2012 issue, you published a 3-Input Stereo Audio Switcher. I am under the impression I could use it to switch two amplifiers outputs to one pair of speakers.

I built the Ultra-LD Mk.4 amplifier and am currently using my AV receiver pre-out to feed it. The Ultra-LD Mk.4 drives the two front speakers while the AV receiver takes care of the centre and surround speakers. It works pretty well for films.

When I listen to music only (stereo mode), I feed the Ultra-LD Mk.4 with the CLASSiC DAC (SILICON CHIP, February to May 2013) which I also built. However, I usually forget to lower the amplifier volume after using the receiver. If so, the music gets very loud when I switch from the receiver to the DAC.

To avoid this situation, I want to feed my speakers either with the A/V receiver (for films) or the Ultra-LD Mk.4 (for music) using this audio switcher and replacing the RCA plugs with pairs of banana plugs. It would also be great to use the same remote with the Ultra-LD Mk.4, DAC and Switcher. Can I do this? (O. A., Singapore.)

● The 3-Input Stereo Audio Switcher cannot be used to switch two amplifier outputs to one pair of speakers. The switcher is only suitable for use with low-voltage and low-current signals at up to 2V RMS and a few milliamps of current. Therefore it cannot be connected between an amplifier output and loudspeaker even if the RCA connectors are replaced with banana plugs.

If you wish to swap amplifier outputs to drive one set of loudspeakers, then a double-pole changeover relay (DPDT) relay with contacts rated at say 10A is suitable, assuming the amplifiers are rated at less than 80W into eight ohms. With the relay coil powered, one set of speakers is driven and with it unpowered, the other set is selected. To achieve this, the loudspeakers are wired to the relay common contacts, the NO contacts to one amplifier and the NC contacts to the other amplifier.

A better solution would be to keep the set-up you are using and attenuate the CLASSiC DAC outputs to match the film sound level. You could use a 10kΩ dual ganged potentiometer with one end of each track connected to a DAC output and the other end to the associated ground. The wiper can then be fed to the Ultra-LD Mk.4 amplifier input.

using a splitter box if necessary? (B. B., Palmerston, NT.)

● Your idea seems quite feasible provided you connect a suitable filter capacitor, say 4700µF 25V, across the output of the transformer and bridge rectifier. The peak output voltage should be comparable to the peak output of about 18V from your solar panels which we assume are 12V types.

Mounting Senator speakers off the floor

I am thinking of building your latest "Budget Senator Speakers", as described in the May 2016 issue, but my problem is the placement. My current speakers, mounted on a large wooden beam some 2.5m high and with a separation of 3m, need replacement. How would this affect the performance of your speakers? Nearly all speakers are now shown floor-mounted.

What difference would you expect? How about an article on speaker placement? (M.D., Paynesville, Vic.)

● Provided your speakers will not be close to an adjacent wall, they should perform well but it would be wise to angle the enclosures, to aim the tweeters at your listening spot. However, finding the best mounting position for speakers in a room is not a simple exercise, even if you have the relevant test equipment.

Ultrasonic Parking Assistant Problem

I built the Ultrasonic Parking Assistant (SILICON CHIP, March 2016) by purchasing the available parts and the pre-programmed microprocessor from your store. I am having a problem with it and I wonder if you can shed any light. Because I purchased the pre-programmed micro I did not install CON4.

When the unit is switched on, it shows the message "Sensor not detected", which it also does if the car is removed from the garage. The various ranges and colours appear to work correctly but the distance reading is never still.

In other words, even with the car parked and the engine switched off the unit is still displaying a range reading which constantly varies anywhere between 50 and 10, with an actual distance between the car and the sensor of 25cm.

After overnight parking the performance is the same, ie, the display is still showing a constantly varying reading. When the car is driven towards the sensor during parking it shows a varying distance with the corresponding screen colour changes but the distance measurement fluctuates all the time.

Thinking that the reflection from the front of the car may be at fault I re-aligned the unit so that it is aimed exactly at the centre of the vehicle licence plate for a reliable reflection but it made no difference. Naturally, with a constantly changing reading, the unit will never go into standby.

The garage is fully enclosed with a roller door and a gyprock ceiling so there is minimal air movement when the doors are closed. I would be grateful for any assistance you can offer. (B. D., Hope Valley, SA).

● What happens if you point the sensor unit at a wall? It should give a steady reading. Have you tried operating it out of the case?

This fault could be due to a number of problems such as a bad solder joint (especially on one of the capacitors or the sensor wiring), a faulty sensor module or strong hash from the power supply. It could possibly be some other faulty component in the circuit.

If it still behaves the same way with the sensor out of the case and pointing at a wall then we suggest closely investigating all the solder joints. If it still doesn't work, it could be a faulty sensor module.

Note: this problem was subsequently tracked down to hash on the 5V switchmode power supply that was used.

No voltage from tracking power supply

I recently purchased a kit from Altronics to build the Dual-Tracking 0-19V Power Supply from your June & July 2010 issues. I have finished the build but when I power it on I can't get any significant voltage out of it (~100mV max displayed). I checked this with a multimeter. Setting the current limit seems to work fine.

I think the issue may be with the transformer or mains wiring, since I probed the voltage between the 15V and 0V connectors on the transformer and only got 1VAC. I also tried probing this voltage with an oscilloscope, but when I touched the ground probe to 0V it blew the fuse in the IEC socket, which I have now replaced.

I'm pretty confident in my soldering abilities and I followed the instructions very carefully, so I don't think there's a problem with the main board. I did hear a couple of small cracks when pushing the spade connectors onto a couple of the IEC socket pins.

Do you have any idea what could be the problem and would you be able to give me some troubleshooting steps, eg, voltages on the main board to probe? (C. L., Moonee Ponds, Vic.)

● It sounds like you have a short circuit to Earth. That would explain why connecting the scope's Earth lead to 0V blew the fuse. Earth should only be connected to the rear panel, transformer frame and front panel (for the Earth banana socket), as shown on page 84 of the July 2010 issue. The most likely place for a short circuit would be between the Earthed rear panel and either REG1, REG2 or REG5.

Use a DMM on continuity test mode to check that there is no connection between any of the transistor tabs and the rear panel. If there is a connection, then that suggests that either an insulating washer is punctured or perhaps the bush between the regulator tab and screw is missing or damaged—see Fig.15 on page 88 of the July 2010 issue for regulator mounting details. The only other location a short circuit could exist is where the Earth lug attaches to the rear of the front panel but that seems unlikely.

If none of that helps, try disconnecting the transformer wires from CON1 and measure the transformer output with the board disconnected. You should get 15VAC between the centre tap connection and each of the two other connections. If that's OK and the unit still isn't working then there is a fault somewhere on the board.

Thermistor arrangement for Burp Charger

I wish to enquire about the Burp Charger for NiMH & Nicad batteries project that appeared in your March 2014 issue, by John Clarke. As the thermistor has to be placed in a hole in the battery pack, I assume that for each battery pack (eg, two or four AAA or

Alternative Uses For Blackout Lamp

I bought a Starke brand "Power Outage Backup" LED lamp from Aldi – see photos. It works in standard bayonet fittings. Most of the time it simply acts like a normal light bulb but during blackouts, somehow you can still switch it on using the normal power switch and it lights up for up to five hours.

Obviously it contains a battery which is charged when power is available and used to drive the LEDs during a blackout but how can it detect whether the switch is on or not when there is no mains power?

The reason I'm asking is that I want to play around with this lamp a bit. I figure that if there is a blackout, it should be possible to remove the lamp from the fitting and carry it around like a torch but if I remove it from the fitting it just goes out.

Is there some way to detach it but keep it illuminated? There is also the possibility that I can carry the lamp around and I can appear to "power it" magically, with no wire connections. What do you think? (G. J., via email.)

● If there is a blackout but the light switch is left on, there will be a low impedance between the two lamp terminals (ie, Active and Neutral) while if the switch is off (regardless of the status of the mains) the lamp circuit will normally "see" a high impedance. It must be sensing this impedance. If its power supply impedance is low but there is no voltage, that means the switch is on but there is no mains power, so it runs the LEDs using its internal battery.

So we assume that all you have to do to get the lamp to switch on while it is disconnected from the 230VAC supply (ie, removed from the socket) is to short out the terminals, eg, with a length of wire. Before you do that, you would be wise to measure across the terminals of the lamp to check whether or not a substantial voltage is present. We don't think it will be high; perhaps only a few volts DC, at most.

So the easiest way to run the lamp in this "bogus" way would be to connect it to a bayonet socket with the terminals shorted.

(Note: this theory proved correct and the reader sent in two photos, with one showing the lamp illuminated – Editor).

AA cells) that a thermistor will need to be fitted into each separate pack. Is that correct? (V.P., Gibraltar).

● We showed a thermistor installed in a battery holder as an example. While you could install a thermistor in each battery holder that you use, you only need to strap the thermistor to the side of the battery pack using Velcro (hook and loop) tape or similar. It can then be removed easily for a different pack.

Make sure that the thermistor makes firm contact with one of the cells.

An even lower-powered Ultra-LD amplifier

I would like to build a stereo amplifier using the Ultra-LD Mk.4 low power modules. I have a 25-0-25V 160VA transformer on hand and need to know what resistors I need to change in order to use ±35V DC supply rails. (D.C., Rotorua, NZ.)

● We suggest changing the original Ultra-LD Mk.4 components to the low-powered version, as per the article in the October 2015 issue, with two slight tweaks: the two 4.7kΩ resistors at the collector of Q3b can be changed to 3.9kΩ each and the resistor at Q4's collector should be changed from 110kΩ to 100kΩ.

Railpower project still relevant

In the September & October 2008 issues of Silicon Chip, you published the Railpower project by John Clarke. I notice that Altronics has now deleted this kit from their catalog. Do you have any plans to publish an updated design in the near future? Is the design still relevant eight years on?

I am aware that there are now DCC controllers but I feel they are more suited to a club environment (where a number of enthusiasts are all operating together) rather than for the home hobbyist where PWM would be more than adequate.

If there are no upgrade plans, are the PCB, pre-programmed microcontroller and any specialised parts still available from the Silicon Chip Online Shop? (K. J., Woodbine, NSW.)

● The circuit design is still quite relevant. If we were to revise the project, we would probably not use the transformer and power supply components but instead use a 17V DC supply intended for a laptop PC as these are very cheap. The programmed PIC is available for sale in our online shop at www.siliconchip.com.au/Shop/9/1282

However, we do not stock the PCBs. They are listed as available from EPE Magazine in the UK who republished this project (with permission) in November 2010, at www.wimborne.co.uk/cgi-bin/sh023462.pl?PN=November_2010.html%23a773_2d774

Equivalent SCR wanted

I built an SCR-based speed controller to drive a 240VAC universal motor, based on a project in *Electronics Australia* in the early 1980s. It's still

Mosfets For Mini Solar Battery Charger

I am looking at making the Mini Solar Battery Charger that appeared in my February 2008 issue of SILICON CHIP. However, I have not been able to get the P-channel and N-channel Mosfets (2SJ607 & 2SK3812/SDP85N03L).

Can you suggest any alternatives that I could use? (B.A., West Sussex, UK).

● We assume that you have not been able to obtain these parts from the designers of this project, Oatley Electronics. If that is the case, we can supply a pack of two logic-level Mosfets, including one IPP230N06L3 N-channel and one SPP15P10PL-H P-channel type, for $7.50 plus postage. They can be purchased at www.siliconchip.com.au/Shop/7

going strong. I would like to build another but am having trouble getting the 2N4444 SCR. Do you know of an equivalent component? Or is there a later design to build? Many thanks. (D. G., via email.)

● We have produced a number of speed controllers along those lines over the years. The most recent was in February 2009 and you can see a 2-page preview at: www.siliconchip.com.au/Issue/2009/February/10A+Universal+Motor+Speed+Controller%2C+Mk.2

There is also a kit available from Altronics – see www.altronics.com.au/p/k6035-10a-240v-ac-motor-speed-controller-kit/

However, that sort of controller does not give smooth low-speed control (and nor would your EA-designed controller). For that you need full-wave speed control and our most recent design for that was in February 2014 – see: www.siliconchip.com.au/Issue/2014/February/230V-10A+Speed+Controller+For+Universal+Motors%2C+Pt.1

Jaycar have a kit for this project – see www.jaycar.com.au/p/KC5526

Alternatively, we can supply the PCB, the programmed microcontroller and some special parts for the February 2014 design from our Online Shop.

Walk-around model railway controller

I would like to build the Walk-around Model Railway Controller from the April & May 1988 issues of SILICON CHIP. It's a very good performer despite its age. Can you tell me where to get the parts to build this or have you produced an improved version since then?

Also, I would like to incorporate a function where the train circles around a loop a number of times, then stops at a station for approximately one minute, then takes off slowly and the cycle repeats. (R. H., via email.)

● As you point out, that project was a very good performer but the PCB has not been available for some years now. However, in July 2013 we published a somewhat simplified circuit on a

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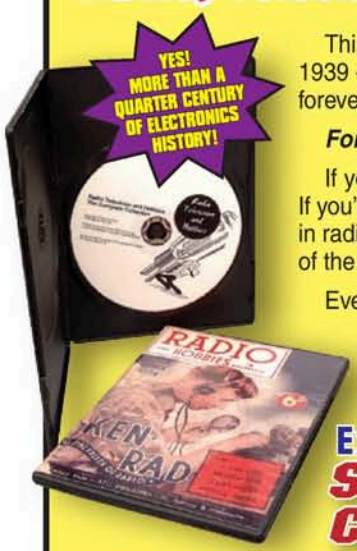

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6-Digit LED Clock For Orienteering

I write with regard to your recent project on the 6-digit LED clock. I am interested in putting together one or two of these clocks for use as a start timer for orienteering events in and around the ACT.

Typically, for major orienteering events, competitors are started in groups every one or two minutes. About five seconds before the minute, the clock beeps on each second, with a long beep on the minute when competitors pick up their map and start on their course. So, in view of the above, I have a few questions.

Could the clock be programmed to beep (more or less) as above, with variable start intervals of 30 seconds, 1, 2, 3 or 4 minutes? Or not beep at all?

Since the clock would be used outdoors, it would need to run off a portable battery supply, 12V or so, which I presume limits me to to using the red LEDs. That in itself is not a problem, but is the display still bright enough to be easily seen in bright daylight? And is there room to put a suitable battery inside the case to run the clock for 4 or 5 hours?

A similar clock is already produced in the UK – see www.finchhouse.org/finchhouse/index.php?page=kitst (kitst = keep it simple timing). The NSW orienteering association has some of these.

A very much more expensive start clock is produced by Emit in Norway: www.emit.no/en/product/emit-start-display-esd2-346

Looking forward to your comments. (B. J., Evatt, ACT.)

● Yes, you could change the clock software to do what you want but you would need to modify the C source code and recompile it. The Microchip MPLAB X Integrated Development Environment is free and the XC32 compiler is available with a free 60-day trial so this should be possible but you would need programming knowledge to do so.

It is possible to run the clock from a 12V battery with the blue or emerald green LEDs but it is not ideal. You would get better brightness with the red ones due to their lower forward voltage. With the appropriate supply voltage, all three of these colours should be quite visible in daylight conditions.

There isn't much room inside the case but you could pretty easily strap a Li-Po pack on the back. Such a pack with a couple of amp-hours of capacity would easily run the clock for 4-5 hours. This would also potentially solve the colour problem, since you could use a 4-cell pack which would be 16.8V when fully charged and 14.4V when mostly discharged.

Another option would be to redesign the case to be deeper but you would need access to a laser-cutter. Or simply find a larger case with a clear lid that will fit both the clock and the battery. Regardless, a 4-cell Li-Po battery is definitely the way to go to power the clock in this type of situation.

smaller PCB, the Li'l Pulser, which is still available. You can see a 2-page preview of the project at www.siliconchip.com.au/Issue/2013/July/Li'l+Pulser+Model+Train+Controller%2C+Mk.2 and you can purchase the PCB at www.siliconchip.com.au/Shop/8/1046

You may also want to add a modification which was published in January 2014 – see www.siliconchip.com.au/Issue/2014/January/Li'l+Pulser+Mk2%3A+Fixing+The+Switch-Off+Lurch

Note that we did not provide for separate hand-held throttles in this design but it would be very easy to tap into the circuit to provide this facility, especially if you have access to the original 1988 articles.

Regarding the second part of your query, we're not really sure how you would implement such a circuit. It would only be applicable to a loop of track and would require an event counter, sensors at the station and a means to over-ride the train controller's circuit. We have not produced such a circuit.

Modifying the Flexitimer

I have built a Jaycar Flexitimer kit (KA1732) but am wondering if it is possible to change the components so that it can operate two hours off, five minutes on, two hours off, five minutes on, etc.

If that can't be achieved with the Flexitimer, what other timer could I use? (G. F., Berowra Heights, NSW.)

● We have published a number of modifications for this popular timer project, as follows:

May 2011: Circuit Notebook – Flexitimer Modification Gives Adjustable On And Off Delay Settings, by Ken Moxham

July 2010: Circuit Notebook – Modifying the Flexitimer For Short Intervals, by Silicon Chip

April 2010: Circuit Notebook – Adding A Restart To The Modified Flexitimer, by John Clarke

April 2009: Circuit Notebook – Modified Flexitimer, by John Clarke

It was the May 2011 modification that provided adjustable on and off periods but it does need extra parts. You will need to purchase the relevant back-issue (printed or online) to see the modifications required. Both are available from our website at www.siliconchip.com.au/Shop/2/610 (printed) or www.siliconchip.com.au/Shop/12/633 (online).

Electric fence controller questions

I have some questions regarding the Electric Fence Controller (Silicon Chip, April 1999). I have a Lanstar fence energiser that failed and was not worth repairing, however the pulse transformer and 30µF charge capacitor were worth salvaging and I have modified the Silicon Chip controller to drive these components by installing a higher power Mosfet and Triac.

I've also applied an air gap and a few more turns of wire to the DC-DC transformer to increase the voltage to 570V. Everything is working fine and there is a good strong spark at the output across a 3mm gap. So I assume the output is around 10kV, the same as the Lanstar unit was. I have attached the circuit for the Lanstar as it may be of interest.

I am putting together a second Silicon Chip controller to have as a spare unit if needed and plan to wind a pulse transformer using a 50W iron-core transformer salvaged from an old video recorder. This transformer has a ratio of four turns per volt. From my reckoning, for a 4ms pulse every 1 second this is equivalent to 0.016 turns

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Ask SILICON CHIP

. . . continued from page 102

per volt (given by 0.004 x 4 = 0.016). For 10kV, that is 160 turns minimum.

The SILICON CHIP pulse transformer has seven turns for its primary, 250 turns on the secondary, 350V input and 3.6kV output. 7T ÷ 350V = 0.02, 250T ÷ 0.02 = 12,500V. I find this confusing. Is there a reason for this difference or is there a mistake in the article? Is it supposed to be 17 turns?

Back in October 1986, *Electronics Australia* published a Fence Controller (EA86ef11) by Colin Dawson. This controller has a pulse transformer with 40 turns on the primary and 500 turns for the secondary with 250V input and 5kV output. 40T ÷ 250V = 0.16, 500T ÷ 0.16 = 3125V. This is confusing as well. Should this be 30 turns or is there some reason for this difference?

The EA controller has a 30µF capacitor, the same as the arrangement I have with the components from the Lanstar energiser. The only real difference is the voltage applied to the capacitor and it looks like they left scope with the voltage to make it a bit more powerful. The pulse transformer would have been much the same size as the one from the Lanstar and the one that I am planning to wind.

I would like some advice regarding the winding of this transformer. I will be pushing 550V into the transformer and with 500 turns for the secondary

Notes & Errata

Pocket TENS Unit for Pain Relief, January 2006: the IR2155 IC used in this project is now obsolete and difficult to obtain. According to International Rectifier, the IRS2153D-PBF is the recommended replacement (see https://ec.irf.com/v6/en/US/adirect/ir?cmd=catProductDetail&productID=IR2155).

Ask SILICON CHIP

. . . continued from page 103

and 30 turns for the primary I figure the output should be close to 10kV.

Now given that the minimum number of turns for the secondary with 10kV output is 160 turns, it may be possible to get away with fewer than 500 turns. I was thinking of say 320 for the secondary and 18 for the primary; this should lower the impedance and take less time to wind. Besides, I have plenty of 0.8mm diameter wire and this is the most I can get on to the former unless I go to 0.6mm.

My questions are as follows:

(1) If I lower the number of turns, will it shorten the pulse length or affect the output voltage?

(2) Could it possibly overload the transformer?

(3) Is it better to stick to 500 turns or possibly more? (D. D., via email).

● The turns ratio of the output pulse transformer was wound to comply with the Australian Standards AS3129. It states that the energy produced by an electric fence is limited to a maximum of five Joules into a 500-ohm load. Open-circuit load voltage is restricted to 10kV (ie, >1MΩ load in parallel with 100pF).

The turns ratio does not necessarily set the voltage that will be delivered to a 500Ω load. The output depends on the pulse width, the impedance of the transformer and the inductance of the windings.

If you use fewer turns on the transformer primary, the transformer may deliver less energy (fewer Joules) to the output. With an unknown core, you will have to experiment with the number of turns and the turns ratio. **The output must ultimately comply with AS3129 for safety's sake.**

Champion for a guitar practice amplifier

I was wondering if the Champion (January 2013) and the Champ (February 1994) amplifiers would be compatible with an electric guitar in their kit form, as sold at Jaycar and Altronics. I am interested in building a simple guitar practice amplifier and both are stocked by stores near me. (O. M., via email.)

● The Champion from January 2013 would be quite suitable. This has sufficient output power for good volume through efficient loudspeakers and the input sensitivity should be sufficient for a guitar without needing the pre-Champion that is incorporated on the Champion PCB.

We don't recommend the Champ from February 1994 for a guitar practice amplifier as the input impedance is too low and output power is insufficient. SC

Next Issue

The August 2016 issue is due on sale in newsagents by Thursday 28th July. Expect postal delivery of subscription copies in Australia between July 28th and August 10th.

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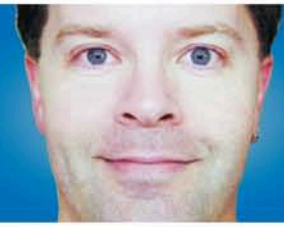

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